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THE

AMERICAN JOURNAL OF SCIENCE

[THIRD SERIES.]

ART. XXXIII.—*Observations on the Derivation and Homologies of some Articulates;* by JAMES D. DANA.

THE term Articulates is used here in preference to Arthropods because the latter group is believed to be not a natural one, Crustaceans and Insects being less closely related to one another, as indicated beyond, than Annelids and Insects.

Derivation of Limuloids and Crustaceans.—As has been suggested by Lankester, it is probable that all the Articulates are successional to the Rotifers. There is reason for believing further that the types of *Annelids*, *Crustaceans*, and probably that of *Limuloids*, had their independent Rotifer origin.

The Nauplius, or larval form of a Crustacean, shows, by its having but 3 pairs of limbs (2 besides an antennary pair) that the type is not successional to a many-jointed Annelid, but rather to some Pedalion-like Rotifer. The discoveries of Prof. C. E. Beecher announced in the preceding and earlier numbers of this Journal leave no doubt that the Trilobites are multiplicate Isopod Crustaceans, precursors of the normal Isopods, as the true Phyllopods, also multiplicate species, were precursors of the Decapods.*

* In the Author's Report on the Crustacea of the Wilkes Exploring Expedition, the Rotifers are made the lowest subdivision of Crustacea (p. 1408); and the Trilobites are placed, with a query, in the subdivision of Tetradecapods as multiplicate forms under the type. In the text above, the expression *true* Phyllopods is used, because most of the so-called Phyllopods of the Paleozoic exhibit, in the specimens, no evidence that they are multiplicate, that is, have an excessive or abnormal number of body-segments or appendages.

The Eurypterids, the early form of the Limuloids, are related to Crustaceans in number of body-segments, it being 19, as in the Tetradecapods; and in the fact that 13 of these 19 segments pertain to the thorax and abdomen. But the wide distinction exists that the Eurypterids have no thoracic or abdominal limbs, and the only true feet which they have are also at base mouth-organs, that is organs that pertain to the head. Moreover, as has been shown, by Packard and others for the Limulus, they do not pass through the Nauplius stage in their development. These diversities and agreements appear to indicate a derivation for the Limuloids nearly like that of the Crustacean type, but probably not *from* Crustaceans. But since Limuloids cannot yet be proved to have existed before the Trenton period in the Lower Silurian, a derivation from some species related to the Ceratiocarids is possible. Since many if not all of the Eurypterids were freshwater or brackish-water species, the transfer to freshwater may have been an incident attending the divergence; and also an explanation of their attaining so great dimensions, freshwater having been their protection. The large Eurypterids, several feet in length, would have been helpless among Sharks and Ganoids.

Derivation of Arachnids.—The line to the lower and earlier Arachnids, that is, to the Scorpions, leads up, according to Van Beneden, Packard and others, from the early Pterygotus-like Limuloids. The early Scorpion, as well as the modern kinds, has the same number of body-segments as a Eurypterus or Pterygotus, namely: 7 thoracic, and 6 abdominal (precisely the normal number in Crustaceans); the same *cephalic* relations of the legs; the same absence of abdominal appendages; a like absence of thoracic appendages from all the segments excepting the first two, and similar functions in the members pertaining to these two segments. Further, according to B. Peach, these early Limuloids sometimes have, like the Scorpions, pairs of "combs" or pectinated organs on the underside of some of the thoracic segments.

But in this change from an aquatic to a terrestrial species the upward progress in structure was great. The 4 posterior pairs of feet in the terrestrial Scorpion have no longer the low-grade feature of serving as jaws as well as feet, but are simply feet; they are the chief organs of locomotion, and only those of the anterior pair are appendages to the mouth. The antennæ are shortened to pincers (falces) that also serve the mouth. The four pairs of feet are thus *cephalic* organs, if comparison be made with the Limuloids and Crustaceans, though in Arachnology they are called *thoracic*. In the later true Spiders, the body had lost its Eurypteroid abdomen, but had still, in Paleozoic species, its distinctly segmented thorax;

and this thorax is the abdomen of Arachnology. It is segmented in some modern species, while in others the subdivisions have become obsolete or are but faintly indicated. The abdomen of the Eurypterid however exists as a slender jointed thread in *Geralinura* of Scudder, of the Carboniferous, which has its Illinois, and also Bohemian, species and has survived till now, in the modern *Telyphonus*.

Derivation of Myriapods and Insects.—*Myriapods* although inferior to Insects, are as yet known only from the early Devonian. The Devonian species, and also those of the Carboniferous, are of the Millepede or lower doubly-multiplicate section of Myriapods with one exception, that of the remarkable few-jointed, caterpillar-like *Palæocampa* of Meek and Worthen.

The fact of a line of succession from Worms to Myriapods and from Myriapods to Insects has not been proved by geological discovery. The derivation of Myriapods from some type of Annelids is zoologically suggested, as long since recognized, by the apparently transitional form of *Peripatus*, a low-grade Myriapod resembling much the larve of some Insects, and by the like multiplicate structure of Annelids and Myriapods. It might be inferred also from the resemblance of the Palæocampa of the Illinois Carboniferous to the caterpillar of an Insect of the genus Arctia, as remarked by Scudder.

Myriapods are regarded as the precursors of Insects on account of their approximate resemblance to the latter in antennæ and the appendages of the mouth, and because also of the wormlike form of most Insect larves, these larves appearing to be survivals of the Myriapod stage. In the change from an Annelid and Myriapod to an Insect, the *multiplicate* feature disappeared and the number of parts became essentially the fixed normal number of the type, both as regards the body-segments and their jointed appendages.

The rise of grade from the Myriapod to the Insect involved the appropriation of the three body-segments of the Myriapod bearing the three anterior pairs of feet (which correspond normally to half the body segments of the head of an Isopod Crustacean) for forming the isolated middle section of the body called the thorax, and the suppression of all the other pairs of feet. In both Spiders and Insects, the change involved also a general concentration of the structure toward the cephalic nervous center, that is a shortening of the range of cephalic control, and especially the distance to the posterior limit of locomotive action. Compared with a Crab, the highest type in the Crustacean series, its superior, an Ant, is a very little thing.

The fact that in low-grade Insects, there is no proper metamorphosis, while in the higher, as they rise in grade, the larval stage is lower and lower in embryonic level, suggests that the larval stage results from an attendant retrograde embryonic change to a line parallel with the Myriapod, and beyond to the memberless condition of a worm. The principle appears to be a general one among animals, and thence, the higher the species the longer the stage of youth.

The relations in body-segments and limbs between the classes of Crustaceans, Limuloids, Arachnids, Myriapods and Insects are shown in the following table. The segments of the body are numbered along the left margin; the zero opposite signifies that the segment, though present has no appendage.

CRUSTACEANS.		LIMULOIDS.			ARACHNIDS.		MYRIAPODS.	INSECTS.
Tetradecapods.		Eurypterus.	Pterygotus.	Limulus.	Scorpion.	Phrynus.	Lithobius.	
1. 1st Ant.	Head.	O	Ant.	Ant.	Falces	Falces	Ant.	Ant.
2. 2d Ant.		M-P.	M-P.	M-P.	M.	M.	M.	M.
3. M.		M-P.	M-P.	M-P.	P.	P.	Mx.	Mx. & L.
4. Mx.		M-P.	M-P.	M-P.	P.	P.	P.	P.
5. Mx.		M-P.	M-P.	M-P.	P.	P.	P.	P.
6. Mx.		M-P.	M-P.	M-P.	P.	P.	P.	P.
1. P.	Thorax.	Fol. P.	Fol. P.	Fol. P.	O.	O.	P.	O.
2. P.		Fol. P.	Fol. P.	Fol. P.	Comb.	O.	P.	O.
3. P.		O	O	Fol. P.	O.	O.	P.	O.
4. P.		O	O	Fol. P.	O.	O.	P.	O.
5. P.		O	O	Fol. P.	O.	O.	P.	O.
6. P.		O	O	Fol. P.	O.	O.	P.	O.
7. P.		O	O	O	O.	O.	P.	O.
1. App.	Abdomen.	O	O	O	O.	O.	P.	O.
2. App.		O	O		O.		P.	O.
3. App.		O	O		O.		P.	
4. App.		O	O		O.		P.	
5. App.		O	O		O.		P.	
6. App.		O	O		O.		15 pairs of feet in Lithobius, 21 in Scolopendra, 200 in some Myriapods.	

In this table, the following abbreviations are used: Ant., antenna; App., pairs of jointed appendages, either pediform or branchial; M., Mandible; Mx., Maxilla; P., feet; M-P., feet that serve also as jaws; Mx. & L. (under Insects), maxillæ and labium; Fol. P., foliaceous or lamellar feet or appendages.

Under the Limuloids, the genus Eurypterus fails of antennæ; but they are present in Pterygotus, and are chelate; and this chelate (or thumb-and-finger) form characterizes also the modern Limulus, the Scorpions and the common Spiders. In the table the two pairs of maxillæ of Insects are assumed to belong to a single body segment, as held by many zoologists, including (as he himself informs the writer) Prof. S. I. Smith; the table shows that, with this admission, the thorax and head of an Insect are essentially homologous with the head of a Tetradecapod Crustacean.

Art. XXXIV.—*On the Crystallization of Herderite;* by S. L. Penfield.

During the past summer Mr. L. K. Stone of Paris, Maine, sent to Prof. H. L. Wells of the Sheffield Scientific School several specimens of an unknown mineral for identification. The specimens were collected at Paris, Me., but not at the noted Mt. Mica locality. They presented well defined, transparent and almost colorless *monoclinic* crystals, measuring up to 2^{mm} in diameter and 6^{mm} in length. The crystals are implanted mostly upon quartz but some are on feldspar. Their hardness is a little over 5. When tested before the blowpipe they at first sprouted and turned white, but afterwards fused at about 4 to a white, blebby enamel, tinging the flame very pale green, indicating phosphoric acid. In the closed tube at a high temperature the crystals whitened, threw off quite violently a fine scaly powder or dust and gave water which showed only a faint acid reaction. The mineral was slowly but completely soluble in hydrochloric acid. As these characters apparently did not agree with the description of any known species, the mineral was supposed to be new and accordingly the best material available for the chemical analysis was carefully selected and eventually separated from any attached quartz or gangue by means of the heavy solution. The pure mineral, amounting to about one and a half grams, and varying in specific gravity from 2·936 to 2·968, was analyzed by Professor Wells to whom the author's sincere thanks are due. The analysis revealed the interesting fact that the mine-

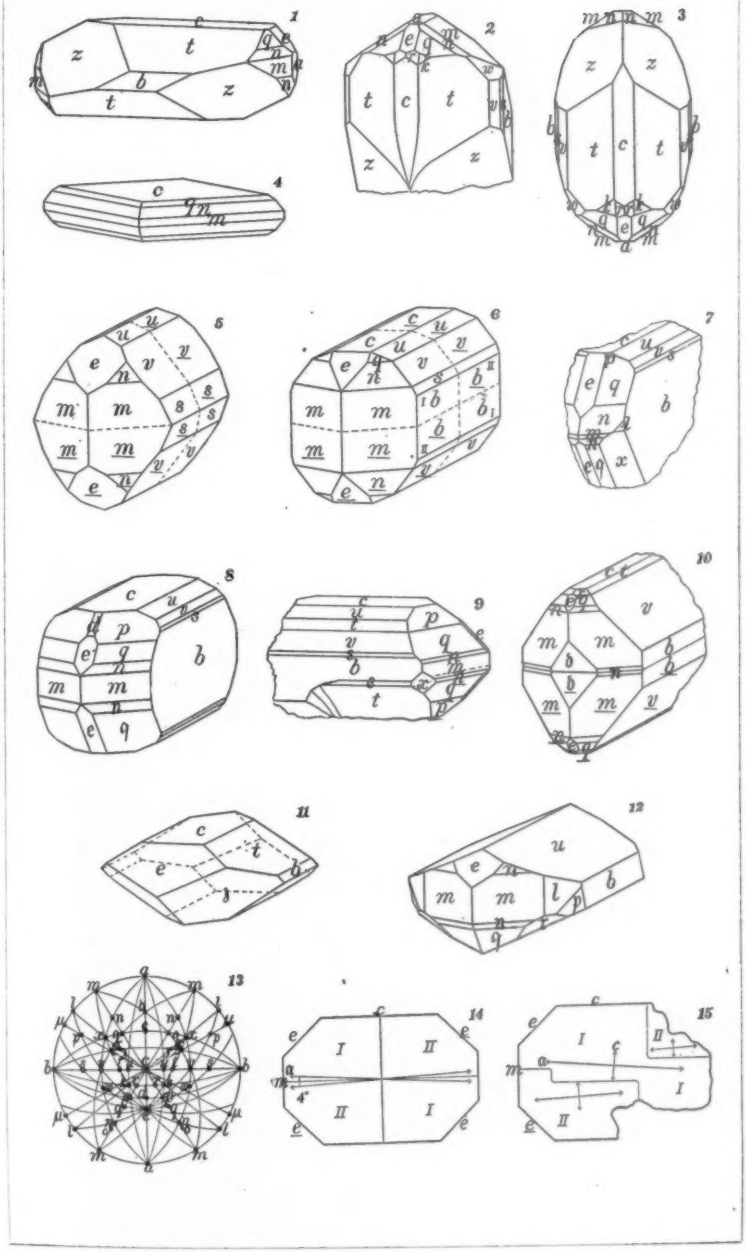
ral is herderite and that it contains practically no fluorine, agreeing in this latter respect with a variety described by Professor Wells and the author* from Hebron, Me. The analyses of the minerals from both localities are as follows:

	Paris.	Hebron, after deducting 5·27 per cent of impurities.	Theory for $Ca[Be(OH)]PO_4$.
Sp. gr.	2·952	2·975	
P_2O_5	44·05	43·08	44·10
BeO	16·13	16·18	15·53
CaO	34·04	[34·35]	34·78
H_2O	5·85	6·15	5·59
F	----	·42	----
Insoluble	0·44	----	----
	100·51	100·18	100·00

The analyses indicate a well defined type of herderite which may well be called hydro-herderite in distinction from the variety containing fluorine. Of the two types the former, $Ca[Be(OH)]PO_4$, occurs quite pure, as shown by the above analyses, and it may readily be told by its peculiar behavior when heated in a closed tube. We have as yet no proof of the existence of a pure fluor-herderite $Ca[BeF]PO_4$. Mackintosh† advanced such a formula for the mineral from Stoneham, Me., but he did not make a test for water or a direct determination of fluorine, the latter being calculated, as he states, from the excess of lime. The anthor in connection with Mr. D. N. Harper‡ proved that the Stoneham herderite contained both hydroxyl and fluorine in the proportion of about 3:2 and proposed the formula $Ca[Be(OH.F)]PO_4$, where fluorine and hydroxyl are regarded as isomorphous. This last type, which may be designated as hydro-fluor-herderite, may be readily distinguished by its behavior in a closed tube, as, when heated intensely, acid water is driven off, etching the glass and yielding a deposit of silica. From the quantity of hydrofluoric acid that is liberated it has been assumed that the fluorine and hydroxyl are in combination with beryllium and not with the more basic calcium.

The most interesting feature of the herderite from this new locality is, however, its *monoclinic crystallization*. The discovery of this has lead to the examination of the mineral from other localities and it has been found, as will be shown in the course of this article, that herderite is always monoclinic and not orthorhombic.

* This Journal, III, xliv, p. 114, 1892.
† This Journal, III, xxvii, p. 137, 1884.
‡ This Journal, III, xxxii, p. 107, 1886.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Among the specimens that were examined from the new locality there were only a few small crystals that were well adapted for measurement with the goniometer and these were always so attached that only a part of their faces were developed. Some of the faces are curved and give uncertain reflections but the majority are good and they are very free from vicinal planes, which are prominent on the Stoneham herderite. In the description of the crystals the position adopted by E. S. Dana* has been retained, and as far as possible, his system of lettering.

The habit of the crystals is shown in figures 1, 2 and 3. Number 1 is drawn with $0\bar{1}0$ in front and No. 2 with 001 vertical, these positions being chosen because they are best adapted for showing the monoclinic symmetry. Figure 3 is a basal projection and from this and the spherical projection, fig. 13, the relations of the forms and the prominent zones can readily be made out. The forms which have been identified are as follows:

a,	100,	$i\text{-}\bar{i}$	*e*,	302,	$-\frac{3}{2}\text{-}\bar{i}$	*r*,	112, $-\frac{1}{2}$
b,	010,	$i\text{-}i$	*t*,	032,	$\frac{3}{2}\text{-}i$	*q*,	332, $-\frac{3}{2}$
c,	001,	0	*v*,	031,	$3\text{-}i$	*n*,	331, -3
m,	110,	*I*	*s*,	061,	$6\text{-}i$	*u*,	$\bar{3}31$, 3
k,	122,	$-1\text{-}\grave{2}$					
w,	3·12·4,	$-3\text{-}\grave{4}$					
z,	$\bar{3}94$,	$\frac{4}{3}\text{-}\grave{3}$					

The axial ratio was calculated from the measurements which are marked by an asterisk in the table of angles. For comparison the ratios derived by Haidinger† from the Ehrenfriedersdorf and by Dana from the Stoneham herderite are also given.

Author	$\dot{a} : \overline{b} : c = 0{\cdot}63075 : 1 : 0{\cdot}42742$	$\beta = 89° 54'$
Haidinger	" " $= 0{\cdot}6261 : 1 : 0{\cdot}4247$	$\beta = 90$
Dana	" " $= 0{\cdot}6206 : 1 : 0{\cdot}42345$	$\beta = 90$

The angle β is very close to 90°, but there can be no mistake about the monoclinic character of the crystals as indicated by the development of the faces. As regards the forms, those shown in fig. 1 are almost invariably present. The basal plane *c* always yields good reflections and the edges which it forms with the dome *t* invariably curve and taper to a point as they approach the pyramid *z*, fig. 2. The edges between *t* and *z* were always rounded, and this is especially true in the vicinity where *c*, *t* and *z* approach one another. The pyramid *z* which, owing to the curved nature, did not yield very satisfactory measurements was surely identified by its location in the zones *m*, *e*, *k*, *t* and *m*, *v*. The pyramids *q* and *n* are commonly striated parallel to their intersection edges.

* This Journal, III, xxvii, p. 229, 1884.
† Phil. Mag., iv, p. 1, 1828.

Some of the measured angles are recorded in the following table, where it will be observed that the agreement with the calculated is usually very satisfactory, thus indicating that the axial ratio is nearly correct. Where the variation is considerable the faces were always either rounded or otherwise poorly adapted for measurement.

	Measured.	Calculated.
$c \wedge a$, 001 ∧ 100 =	89° 54′*	
$c \wedge e$, 001 ∧ 302 =	45 25*	
$b \wedge v$, 010 ∧ 031 =	37 57*	
$c \wedge m$, 001 ∧ 110 =	-----	89° 55′
$m \wedge m$, 110 ∧ 1$\bar{1}$0 =	64 25	64 29
$b \wedge m$, 010 ∧ 110 =	57 47	57 45½
$c \wedge r$, 001 ∧ 112 =	21 52	21 49
$r \wedge r$, 112 ∧ 1$\bar{1}$2 =	22 43	22 52½
$c \wedge q$, 001 ∧ 232 =	50 8	50 11
$q \wedge q$, 332 ∧ 3$\bar{3}$2 =	48 20	48 22
$c \wedge n$, 001 ∧ 331 =	67 7	67 20
$n \wedge n$, 331 ∧ 3$\bar{3}$1 =	58 56	58 59
$b \wedge n$, 010 ∧ 331 =	60 30½	60 30½
$c \wedge n$, 001 ∧ $\bar{3}$31 =	------	67 29

	Measured.	Calculated.
$m \wedge n$, $\bar{1}$10 ∧ $\bar{3}$31 =	22° 23′	22° 36′
$n \wedge n$, $\bar{3}$31 ∧ 3$\bar{3}$1 =	-----	59 3
$c \wedge k$, 001 ∧ 122 =	-----	28 35½
$k \wedge k$, 122 ∧ 1$\bar{2}$2 =	-----	44 3½
$r \wedge k$, 112 ∧ 122 =	11 3	10 35½
$c \wedge t$, 001 ∧ 032 =	32 46	32 40
$t \wedge t$, 032 ∧ 0$\bar{3}$2 =	65 36	65 20
$b \wedge s$, 010 ∧ 061 =	21 17	21 18
$a \wedge v$, 100 ∧ 031 =	89 55	89 56
$a \wedge w$, 100 ∧ 3·12·4 =	72 34	72 35
$c \wedge w$, 001 ∧ 3·12·4 =	-----	54 2
$w \wedge w$, 3·12·4 ∧ 3·$\bar{1}$2·4 =	-----	97 36
$c \wedge z$, 001 ∧ $\bar{3}$94 =	-----	47 26
$b \wedge z$, 010 ∧ $\bar{3}$94 =	49 ..	49 22½

Optical properties.—Sections parallel to the clinopinacoid show inclined extinction. With yellow light, Na flame, the axis of greatest elasticity, which is the acute bisectrix, was found to make an angle of $+2\frac{1}{2}°$ with the clino axis, hence, as the axial inclination β is approximately 90°, c is inclined $2\frac{1}{2}°$ to $\dot{c}$ in the acute angle β. The plane of the optical axes is the clinopinacoid and the double refraction is negative and rather strong. For the determination of the mean index of refraction a prism was prepared with its edge parallel to the ortho axis. Owing to the character of the material the prism was small and its optical orientation only approximately correct. The results of the measurements are given in tabular form below. Two plates were prepared, one at right angles to the acute bisectrix, the other parallel to the base, which is approximately at right angles to the obtuse bisectrix. The first of these was so small that the divergence of the optical axes could not be observed in air but was determined in α-monobromnaphthaline ($ny = 1{\cdot}6572$). The results are as follows, all made with yellow light, Na flame:

From prism: $\alpha = 21° 58'$, $\delta = 14° 16'$, hence $\beta = 1{\cdot}632$

$2H\alpha$ =	70° 44′	hence	$2V\alpha$ = 71° 59′
$2H\rho$ =	105 1	hence	$2V\rho$ = 107 21
			179° 20′
		Theory,	180 00

Also from $2H\alpha$ and $2H\rho$ there were calculated for comparison $2V\alpha = 72° 12'$ and $\beta = 1{\cdot}628$. The first of these agrees

very well with the value given above, the second varies 0·004 from β derived from the prism and the mean of the two determinations 1·630 may be accepted as very nearly correct. The dispersion was $\rho > v$ and was decidedly inclined, the borders of one hyperbola being much more brilliantly colored than the other.

Herderite from Hebron, Maine.

The occurrence of this hydro-herderite has already been referred to and the analysis given. The habit of the crystals is represented in fig. 4. Only a very little of this material was found, and the crystals were not well adapted for accurate measurement. As stated in the original description, one of the best measurements that was made was $n \wedge n$, $331 \wedge \bar{3}31 = 102° 22'$ which does not agree well with the angle calculated by Dana, 103° 24′, but does, however, compare very favorably with the angle calculated from the hydro-herderite from Paris. If the crystals are twinned about the basal plane, according to a method to be described later, the calculated angle should be 102° 25′ and if they are simple, 102° 41′.

Herderite from Stoneham, Maine.

On the crystals from this locality the following forms have been identified:

b, *c*, *m*, *e*, *s*, *v*, *t*, *q*, *n* and *u*

corresponding to the herderite from Paris, and in addition:

l, 120, i-$\dot{2}$	*e*, $\bar{3}02$, $\frac{3}{2}$-$\bar{1}$	*p*, 111, −1	*x*, $\bar{3}62$, 3-$\dot{2}$
d, 101, −1-$\bar{1}$	*u*, 011, 1-$\dot{1}$	*q*, $\bar{3}32$, $\frac{3}{2}$	

Of these all except *d*, which is mentioned by Hidden,* were observed by Dana, while the prism μ, 130 and the pyramid y, 3-$\dot{3}$ observed by him have not been found by the writer, and the position of y in the monoclinic system cannot therefore be determined. Figures 5 and 6, which, except for the lettering, have been copied from Dana, represent the prevailing combinations. The crystals are penetration twins and imitate orthorhombic symmetry, similar to the crystals of stilbite. The twinning plane can be either the base or the orthopinacoid; β being very near 90°, and the character of the faces such that sufficiently accurate measurements cannot be made to determine this point. Considering the faces in the upper front and lower rear segments as in normal and parallel position, the lettering on the remaining faces has been underlined

* This Journal, III, xxxii, p. 209, 1886.

to signify that they are in twin position. Fig. 7 represents a fragment which was detached from a specimen in the Brush collection. It illustrates monoclinic symmetry in the development of *e*, *q* and *n* larger than ε, ϙ and ν and also in the occurrence of the positive pyramid *x* between *b* and ϙ and not between *b* and *q*. A thin section was prepared from this crystal parallel to *b* and it showed no indication of twinning. Fig. 8 represents the development of the forms on a crystal in the Bement collection. This was so attached that the majority of its faces could be observed and the monoclinic character is well shown by the occurrence of *d* and *p* in the upper front and lower hind segments only.

Fig. 9 represents a crystal in the Bement collection which is reported as being the largest herderite ever found at Stoneham and has already been described in this Journal by Mr. Hidden.* Its actual dimensions parallel to the crystallographic axes are $\dot{a}$ 23^{mm}, $\overline{b}$ 25^{mm} and $\dot{c}$ 18^{mm}. The crystal was attached at one extremity of the $\dot{a}$ axis and has been drawn with $0\bar{1}0$ in front. It is twinned, and what is undoubtedly the line of twinning may be distinctly traced across the *m* and *x* faces, as indicated by the dotted line in the figure. That portion of *x* above the twinning line is quite perfect, and with reference to the upper half of the crystal, it is situated in its normal position for monoclinic symmetry as a positive hemi-pyramid. The lower portion, however, is very uneven and vicinal and occupies the position of a negative hemi-pyramid, but this has not been included in the list of forms, as this is the only occurrence of it that has been observed and it is not a perfect face but rather an attempt to complete the *x* face in the upper portion of the twin.

As has already been stated the material from Stoneham is a hydro-fluor herderite with OH : F = about 3 : 2 and it presents an excellent opportunity for comparison with the hydro herderite from Paris, and of observing the variations in the physical properties produced by the partial substitution of fluorine for hydroxyl. Unfortunately the crystal faces have such a strong tendency to vicinal development that it is difficult to obtain reliable measurements. Owing to the absence of visible reëntrant angles on twin crystals the inclination β must be very near 90° but it could not be accurately measured. On two crystals which were selected on account of the perfection of their faces the following measurements were made, of which those under I are especially good :

* Loc. cit.

	Measured I.	Measured II.	Calculated, Dana.	Calculated for hydro-herderite.
$m \wedge m$, $110 \wedge 1\bar{1}0$ =	----	63° 57′	63° 39′	64° 29′
$n \wedge n$, $331 \wedge 3\bar{3}1$ =	58° 19′	58 21	58 17½	58 59
$q \wedge q$, $332 \wedge 3\bar{3}2$ =	----	47 58	47 52	48 27
$s \wedge s$, $061 \wedge 0\bar{6}1$ =	137 12	----	137 2	137 23½

It will be observed in the above that the measurements agree very well with the angles calculated by Dana but vary considerably from those found on hydro-herderite. The axial ratio established by Dana is therefore retained, and is repeated below along with the author's ratio for hydro-herderite:

Hydro-fluor-herderite $\dot{a} : \bar{b} : \bar{c} = 0{\cdot}62060 : 1 : 0{\cdot}42345$ β = nearly 90°
Hydro-herderite " " $= 0{\cdot}63075 : 1 : 0{\cdot}42742$ $\beta = 89° 54'$

The partial substitution of fluorine for hydroxyl has had, therefore, an appreciable effect upon the axial ratio, shown especially by a perceptible shortening of the a axis. It may also be pointed out that the specific gravity of the Stoneham mineral, 3·006–3·012, is greater than that of the hydro-herderite from Paris and Hebron, 2·952–2·975, which might be expected, as fluorine with an atomic weight of 19 is heavier than hydroxyl with a molecular weight of 17.

Optical properties.—Several clinopinacoid sections that were prepared showed an inclined extinction of about +2° when measured with yellow light. Sections from twin crystals like figs. 5 or 6 revealed the twinning beautifully in polarized light. Fig. 14 represents an ideal section, the opposite portions I and I as also II and II extinguishing simultaneously. Fig. 15 represents the actual disposition of the Parts I and II in a section from a crystal like fig. 6, the arrows indicating the directions of extinction.

The mean index of refraction was determined by means of a prism cut with its edge parallel to the ortho axis and the divergence of the optical axes by a plate cut normal to the acute bisectrix. The results, all determined in yellow light, Na flame, are as follows:

	Hydro-herderite.
From prism $\alpha = 22° 55'$ $\delta = 14° 24'$ hence $\beta = 1{\cdot}612$	$\beta = 1{\cdot}630$
$2E_a = 128° 25'$ hence $2V_a = 67\ 56'$	$2V = 71° 59'$
$2H_a = 66\ 0$ hence $2V_a = 68\ 7$	71 59

The double refraction is negative. The dispersion is $\rho > v$ and is distinctly inclined. The indices of refraction have been determined by Bertrand* as follows:

$$\alpha = 1{\cdot}621 \qquad \beta = 1{\cdot}612 \qquad \gamma = 1{\cdot}592$$

* Bull. Soc. Min. de France, ix, p. 142, 1886.

The divergence of the optical axes has been measured by Des Cloizeaux.* His optical preparation was undoubtedly cut from a twin crystal, for he states that on both sides of the bisectrix two sets of rings were visible, which may readily be understood by reference to fig. 14, as a section parallel to the ortho-pinacoid would be approximately normal to two bisectrices. He gives $2E_a$ for the inner hyperbolæ 121° 22′ and for the outer 130° 2′. The true value should be about midway between these. From the study of the optical properties we learn, therefore, that, by the partial substitution of fluorine for hydroxyl, the position of the axes of elasticity has not materially changed but the mean index of refraction β and the divergence of the optical axes have decreased.

Herderite from Auburn, Maine.

The material from this locality as shown by the closed tube reaction is a hydro-fluor-herderite, and as far as known to the author is represented by a single specimen in the Bement collection and two crystals belonging to Mr. T. F. Lamb of Portland, Maine. On the specimen in the Bement collection there is one crystal which is almost colorless and transparent and has the habit shown in fig. 10. It is attached to albite and a large imperfect herderite and measures parallel to the axial directions $\dot{a}$ 8^{mm}, $\bar{b}$ 8^{mm}, and $\dot{c}$ 11^{mm}. It is twinned and shows a reëntrant angle formed by the faces of the dome $\mathfrak{d}$, $\bar{3}01$. This form is strongly vicinal in its development, and was not identified by measurement but by its position in the zones v, m. Some of the large faces are dull and not adapted for measurement but the forms m, n and q, except for a slight striation parallel to their mutual intersections, are remarkably perfect and yielded the following measurements:

		Stoneham herderite.	Hydro-herderite.
$m \wedge m$, upper crystal	63° 53′	63° 39′	64° 29′
$m \wedge m$, lower crystal	63 52	" "	" "
$n \wedge n$, upper crystal	58 31	58 17½	58 59
$n \wedge n$, lower crystal	58 30	" "	" "
$q \wedge q$,	47 54	47 52	48 22
$m \wedge n$,	22 22	22 33	22 35
$m \wedge q$,	39 36½	39 42	39 39

From the values of $m \wedge m$ and $n \wedge n$, which are undoubtedly very accurate, it may be assumed that this variety contains less fluorine than the Stoneham mineral as the values are slightly greater and thus approach the hydro-herderite. The crystals from the collection of Mr. Lamb are in habit similar to the one

* Bull. Soc. Min. de France, vii, p. 132, 1884.

just described, but they are not so perfect and they do not show the reëntrant angle.

Herderite from Greenwood, Maine.

In this township herderite has been found at two localities. At one of these it is a hydro-herderite and, as represented by a small specimen in the Brush collection and by several crystals belonging to Mr. Geo. L. Noyes of Norway, Me., it occurs in crystals measuring 15^{mm} in diameter, but poorly developed and presenting no forms that could be accurately measured on the reflecting goniometer; with the contact goniometer, however, the following were identified: *b*, 010; *c*, 001; *t*, 032 and ȝ, $\bar{3}64$, $\frac{3}{2}$-2. The development of the forms is shown in fig. 11, ȝ having been observed only on crystals from this locality.

At the second locality it is a hydro-fluor-herderite and is represented only by a single specimen belonging to Mr. Noyes. This shows several herderites attached to a large quartz crystal. The largest herderite measured parallel to the axial diameters *a*, 9^{mm}; *b*, 5^{mm} and *c*, 3$\frac{1}{2}^{mm}$ and had the habit shown in fig. 12. The crystals were not well adapted for measurement with the reflecting goniometer and they were not detached from the quartz, but the forms were identified by approximate measurements made from wax impressions of the faces. The following were observed: *b*, 010; *m*, 110; *l*, 120; *e*, 302; *u*, 011; *n*, 331; n, $\bar{3}31$; q, $\bar{3}32$; r, $\bar{1}21$, 2-2̆ and p, $\bar{3}91$, 9-3̆. The last two have been observed only on the crystals from this locality. The forms q, r and p round into one another and in this respect the crystals resemble those from Paris, where the positive hemi-pyramids are curved and indistinct.

Herderite from Ehrenfriedersdorf, Saxony.

The material from this locality is extremely rare and the author has had no opportunity of examining it. It is undoubtedly monoclinic and the orthorhombic habit described by Haidinger is the result of twinning. In the description given by Des Cloizeaux* of the optical properties it is very evident that he was dealing with a twin crystal as he states that about the acute bisectrix three sets of ring systems were observed. The following values for 2E are given 124° 35′, 123° 10′ and 122° 24′. From the axial ratio given on page 331 it would be expected that the composition of the mineral is intermediate between that of the Stoneham and Paris herderite.

Conclusions.—As has been shown, herderite is a mineral of variable composition and it seems best to designate the dif-

* Loc. cit.

ferent varieties by a suitable prefix. As we speak of fluor-apatite and chlor-apatite, so we can distinguish hydro-herderite, fluor-herderite, if the pure compound is ever found, and for the isomorphous mixture of the two, hydro-fluor-herderite. The axial ratios and other physical properties vary with the composition and the results which have been given in the course of this article will serve as an additional contribution to our knowledge of the isomorphism of fluorine and hydroxyl.

The following is a list of the twenty-nine forms which have been observed on the different varieties of herderite, the accompanying letters signifying the prominent localities: A. Auburn, E. Ehrenfriedersdorf, P. Paris, S. Stoneham and G. Greenwood. The relations of these may be seen by reference to the spherical projection, fig. 13.

Pinacoids.			*Pyramids.*		
a,	100,	i-$\bar{i}$	E. P.	*r*,	112, $-\frac{1}{2}$	A. P.
b,	010,	i-$\dot{i}$	A. P. S. G.	*p*,	111, -1	E. S.
c,	001,	*O*	A. E. P. S.	*q*,	332, $-\frac{3}{2}$	A. P. S.
Prisms.				*n*,	331, -3	A. E. P. S. G.
m,	110,	*I*	A. E. P. S. G.	*o*,	441, -4	E.
l,	120,	i-$\grave{2}$	S. G.	*k*,	122, -1-$\grave{2}$	P.
μ,	130,	i-$\grave{3}$	S.	*w*,	3·12·4, -3-$\grave{4}$	P.
Ortho-domes.				*y*?	131, -3-$\grave{3}$	S.
d,	101,	-1-$\bar{i}$	S.		$\bar{1}31$, 3-$\grave{3}$	S.
e,	302,	$-\frac{3}{2}$-$\bar{i}$	A. P. S. G.	*q*,	332, $\frac{3}{2}$	P. S. G.
e,	$\bar{3}02$,	$\frac{3}{2}$-$\bar{i}$	S.	*n*,	$\bar{3}31$, 3	A. S. G.
b,	$\bar{3}01$,	3-$\bar{i}$	A.	*j*,	$\bar{3}64$, $\frac{3}{2}$-$\grave{2}$	G.
Clino-domes.				*r*,	$\bar{1}21$, 2-$\grave{2}$	G.
u,	011,	1-$\dot{i}$	S. G.	*x*,	$\bar{3}62$, 3-$\grave{2}$	S.
t,	032,	$\frac{3}{2}$-$\dot{i}$	A. E. P. S.	*z*,	$\bar{3}94$, $\frac{9}{4}$-$\grave{3}$	P.
v,	031,	3-$\dot{i}$	A. P. S.	*p*,	$\bar{3}91$, 9-3	G.
s,	061,	6-$\dot{i}$	E. P. S.			

As regards the localities where this rare mineral is found, those in Maine are all within a few miles of one-another, Greenwood, Hebron, Paris and Stoneham being in Oxford County while Auburn is an adjoining township in Androscoggin County. These localities have something in common with the only other known one for herderite, the tin mines of Ehrenfriedersdorf in Saxony, since both are regions of granites and gneisses, and the mineral occurs associated with cassiterite, topaz and beryl in both cases.

As regards the position of herderite in a natural system of classification it seems most closely related to the monoclinic wagnerite-triplite-triploidite group. Although a close relation can be seen between the *a* and *b* axes the relations of the vertical axes and of the inclination β are not so clear.

			a	: b :	c	β
Hydro-herderite,	Ca[BeOH	PO_4	0·6307	: 1 :	0·4274	89° 54′
Hydro-fluo herderite,	Ca[Be(OH . F)]	PO_4	0·6206	: 1 :	0·4234	very near 90°
			$\frac{1}{2}a$	: b :	c	
Wagnerite,	Mg[MgF]	PO_4	0·6362	: 1 :	1·5059	71° 53′
Triplite,	R[RF]	PO_4	?	: ? :	?	?
Triploidite,	R[ROH]	PO_4	0·6190	: 1 :	1·4925	71 46
Sarkinite,	Mn[MnOH]	AsO_4	0·6672	: 1 :	1·5154	62 13½

R = Mn and Fe

In this group fluorine and hydroxyl are isomorphous, and triploidite described by Brush and Dana,* being isomorphous with wagnerite and having undoubtedly the same structural formula as triplite, gave the first instance in which this fact was observed.

In conclusion the author takes pleasure in expressing his sincere thanks to Messrs. C. S. Bement of Philadelphia, Pa., G. L. Noyes of Norway and T. F. Lamb of Portland, Me., for the loan of specimens from their private collections and to Mr. L. K. Stone of Paris, Me., for the supply of material from the new locality.

Laboratory of Mineralogy and Petrography,
Sheffield Scientific School, January, 1894.

Art. XXXV.—*Additional Note on Leucite in Sussex Co., N. J.;* by J. F. Kemp.

In the Journal for April, 1893, pp. 298–305 the writer described a "Basic Dike near Hamburg, N. J., which has been thought to contain Leucite." The paper dealt with a dike that cut blue, apparently Lower Silurian limestone, was 15–20 feet wide and situated about one and one-half miles northwest of Hamburg, N. J. The dike contained some curious spheroids that strongly suggested leucite, but which were altered in every case to a mass of analcite, calcite, and feldspar. From this it was concluded that fresh material would be necessary to decide the presence of this rare and interesting mineral, although the nearness of the elaeolite-syenite at Beemerville, gave additional reason to suspect it. The past summer, being again in the region, the writer visited the extensive quarries for limestone, that have been opened up at Rudeville, which is over on the opposite side of an Archæan ridge (Hamburg Mountain), from Hamburg and the first mentioned dike. The white crystalline limestone is cut by a dike about 12 feet wide,

* This Journal, III, xvi, p. 42, 1878.

with some smaller offshoots, but with a strike in the large one of N. 45° W. and a dip of 75° N. The dike had been opened up to a depth of 20 feet or more below the surface and appeared quite fresh. Most interesting of all, it was copiously provided with the leucitic spheroids, of which an abundant supply was gathered for investigation. It should be stated that it is the same dike as the one mentioned by F. L. Nason in the Annual Report of the N. J. State Geologist, 1890, p. 35, and determined by Dr. G. H. Williams as mica-diabase in an altered condition, Dr. Williams evidently recognizing its affinities with the one in the mines at Franklin Furnace. In the fresh condition it is, in the specimens with the spheroids, precisely like the earlier mentioned Hamburg dike. Although this is three miles away, and not exactly in the same line of strike, the two dikes are so near it as to give ground for the suspicion that they are the same rock body. Ten sections were prepared in three of which there appeared some apparently unaltered material in the midst of the analcite and other secondary products. One of these was cleaned of balsam, and on one-half the gelatinizing and staining test was tried. The secondary products gelatinized and stained readily; the supposed fresh material was not affected. On the other portion in small, carefully selected grains, the test for fluo-silicates was tried. Abundant cubes of potassium fluo-silicate* were obtained, with but little of the hexagonal sodium salt, much less, in fact of the latter, than the bausch-analysis of the altered spheroids, published in the writer's previous paper (p. 303) would indicate for their general mass. In one of the slides the characteristic twinning of leucite is also developed.

It would seem therefore to be quite certain that there actually is in Sussex Co., N. J., a leucite dike rock, associated with the elaeolite-syenite, and that the determination of a piece of the earlier described dike, by Dr. E. Hussak,† as leucite-tephrite, although based on altered material and thought by the writer at the time to be premature, really is substantiated by the discovery of satisfactorily fresh material. But it is also quite true that similar spheroids formed entirely of feldspar have developed in the mica-diabase dike at Franklin Furnace, showing thus that instability of the leucite molecule, which has been elsewhere met.

*These do not appear at once and are only to be obtained by redissolving the first crop in water or dilute HF, and recrystallizing.

†Neues Jahrbuch, 1892, II, 153. The material was derived from J. F. K. through O. A. Derby.

Art. XXXVI.—*On some Phonolitic Rocks from the Black Hills;* by L. V. Pirsson.

For our knowledge of the geology of the Black Hills and of the occurrence and distribution of the igneous rocks of the region we are chiefly indebted to Newton.* Crosby† has also shown that the greater part of the younger eruptives are to be considered as occurring in the form of laccolites. Our information in regard to the petrographical character of these rocks is due to Caswell,‡ who studied the suite of specimens gathered by Newton. This was one of the earlier contributions to American petrology, and when we consider the amount of knowledge available on the subject at that time, it was an excellent and careful piece of work.

Reading between the lines of Caswell's report however and possessed of the facts which the great advance in petrographical knowledge during the past fifteen years has furnished we can see that many of the rocks studied by Caswell were of great interest, unusual in character and that they possessed relations not then brought out.

This was shown by an examination of several specimens from the region which have come into the writer's hands from various sources to be mentioned later and it was therefore decided to study them more in detail with the results given in the present article.

Phonolite.

This rock is definitely mentioned by Caswell, as occurring at Black Butte and he gives a figure and description of it.§ From the facts stated by him it would seem to be present also in other localities. Thus the rock from Bear Lodge, or as it is now commonly called, the "Devil's Tower," an isolated butte near the Little Missouri Buttes on the northwest border of the region and described by Newton‖ as having a remarkable columnar structure is said to gelatinize readily in acid. It is described as sanidine trachyte.

A specimen of this rock has come into possession of the writer through the kindness of Mr. Geo. Leavenworth of New Haven, who visited the locality in 1889. Both in macroscopic appearance and in thin section it agrees quite well with the description given by Caswell but differs in some important characters. It may also be reasonably inferred that the rock

* Geol. of Black Hills of Dakota, U. S. Geog. and Geol. Surv. Rocky Mts., Washington, 1880.

† Proc. Bost. Soc. Nat. Hist., vol. xxiii, p. 511, 1888.

‡ Geol. Black Hills, as above, Chap. vii, p. 471, Micro. Petrog.

§ Op. cit., p. 503. Plate I, fig. 3.

‖ Op. cit., p. 201.

would vary some in different parts of the mass. For Caswell's description the reader is referred to the original memoir as it would be too long to quote here.

The specimen collected by Mr. Leavenworth shows a dense felsitic looking groundmass of a dark gray color with somewhat greasy luster, very thickly dotted with white or pale gray feldspar phenocrysts which attain a size of 1^{cm} in diameter. Sometimes they are columnar on the *à* axis and sometimes short and stout in their habit. They are so thickly crowded as to form a very considerable proportion of the rock mass. Between them lie occasional small black prisms of augite.

In thin section the microscope discloses the following minerals: *feldspar*, *pyroxene*, *titanite*, *apatite* in the first generation and *feldspar*, *nephelite*, *ægirine* and *sodalite* (?) in the second. The large feldspar phenocrysts sometimes show a zonal structure which is indeed plainly visible on the hand specimen where any process of alteration has taken place, as on a weathered rock surface—the center and certain zones being more affected than the outer mantle and remaining parts. Generally they are very fresh, showing only an occasional trace of decomposition along a cleavage crack. Between crossed nicols they sometimes reveal the zonal structure but never any appearance of microperthite from intergrown albite lamellæ and never any twinning save that according to the Carlsbad law.

Since the chemical analysis of the rock—given later—had shown such an excess of soda over potash it was inferred that this feldspar might be anorthoclase and an analysis of it was therefore made.

To obtain material clear glassy fragments of the phenocrysts were first picked by hand, crushed fine enough to pass through a 100 mesh (to the inch) sieve and then washed free from dust and separated by the potassium mercuric iodide solution. They floated readily at 2·614 which would separate any albite (none sank however) and fell at 2·557 which would support any zeolites or decomposed matter. A considerable portion fell at 2·59 and the average specific gravity was between 2·58 and 2·59. Seen under the microscope the material consists of clear homogeneous grains. The analysis gave:

		Ratio.		
SiO_2	66·44	1·1073		6
Al_2O_3	19·12	·1854		1·005
Fe_2O_3	0·56	----		
CaO	tr.	----		
Na_2O	7·91	·1274	·1815	·984
K_2O	5·10	·0541		
H_2O (ign.)	0·57	----		
Total	99·70			

Neglecting the small amount of water and ferric oxide—the latter due to minute amounts of limonite infiltrated into cleavage cracks—the ratios are those of a normal feldspar in which Or : Ab : : 1 : $2\frac{1}{3}$.

Attempts made to measure the cleavage angle of $c(001) \wedge b(010)$ were not successful as the cleavages were too imperfect to reflect light well and measurements could not be made within 1° with accuracy. The cleavage parallel to $b(010)$ is much better than that parallel to $c(001)$. Such cleavage plates resting on $c(001)$ between crossed nicols extinguish parallel to the edge of $c(001)$ on $b(010)$ or so nearly that no appreciable deviation could be seen with the Bertrand ocular or in monochromatic light; resting on $b(010)$ they have a positive extinction angle of about 9° and in convergent light show the obtuse bisectrix c about perpendicular to the field. The feldspar is therefore a soda-orthoclase.

From these results it would seem that soda-orthoclase or anorthoclase is probably a more common constituent of phonolitic and trachytic rocks than might be supposed from their petrographic description. The concealment of the triclinic character, produced very probably by sub-microscopic or even intimate molecular twinning according to the albite law, would naturally lead to confusion with sanidine while examination of cleavage plates of such material, giving only a slightly increased angle in the positive sense on $b(010)$ and a somewhat higher specific gravity, would scarcely yield sufficient data for reliable conclusions and it is evident that only chemical analysis combined with these can safely establish the precise nature of the mineral.*

Pyroxene.—This is ægirine-augite with characteristic color, pleochroism and extinction. Dispersion of the optic axes is marked. It is zonally built, the ægirine molecule increasing toward the periphery which is finally surrounded by a deep green ægirine mantle. This was evidently growing during the final stage of consolidation as the minerals of the groundmass are idiomorphic against it or else actually imbedded in it. *Titanite* occurs in characteristic lozenge shaped cuts which are almost invariably twinned. The *groundmass* is made up mostly of small lath-like feldspars with Carlsbad twinning arranged in trachytic structure and scattered amidst them are shreds and rods of ægirine and very small idiomorphic nephelites. These latter are very clear and colorless and often bounded by the ægirine shreds as is common in phonolites. They are easily told by their hexagonal basal cuts, dark between crossed nicols and short rectangular prismatic ones with

* Conf. also, article by Wolff and Tarr, Bull. Mus. Comp. Zool. Cambridge, vol. xvi, 1893, pp. 230–231).

parallel extinction and by their very low single and double refraction. There appear also small hexagonal sections of a mineral which is full of dusty inclusions and always isotropic. It is supposed to be of the sodalite group which is also indicated by the chlorine shown in the analysis. Patches of a zeolite in radial structure sometimes occur.

The powdered rock gelatinized readily with hydrochloric acid and no effervescence of CO_2 could be seen. A chemical analysis of it yielded the following results.

Sp. G. 2·582.		
	SiO_2	61·08
	TiO_2	0·18
	Al_2O_3	18·71
	Fe_2O_3	1·91
	FeO	0·63
	MnO	trace
	CaO	1·58
	BaO	0·05
	MgO	0·08
	Na_2O	8·68
	K_2O	4·63
	H_2O (ign.)	2·21
	Cl	0·12
	SO_3	trace
	Total	99·86
	O = Cl	0·03
		99·83

To be noted is the very small amount of bivalent metallic oxides present and the great excess of soda over potash.

A phonolite occurring in El Paso County, Colorado, has been described by Cross.* It is the only one thus far in North America which has been investigated.† The analysis of it is almost identical with that just given and shows the same excess of soda over potash. So also do the acmite trachytes from the Crazy Mts. described by Wolff and Tarr.‡ In this respect these rocks are noteworthy among American occurrences and

* Proc. Colorado Sci. Soc., 1887, p. 167.

† Recently A. Osann (Geol Surv. Texas, Ann. Rep. 1892, p. 130) has briefly mentioned phonolites as occurring in the Trans Pecos district, Texas. This makes the third American locality. E. Goldsmith has described so-called phonolites from several localities in eastern Pennsylvania, but since he states that these rocks contain plagioclase, hypersthene and quartz and does not mention nephelite it is not likely that the majority of petrographers will agree with his determinations. His chief reason for calling them phonolites seems to be due to the fact that the rocks split into thin plates and ring when struck with the hammer. He calls them *gabbro phonolites!* and seems to have been unaware of the previous work of Cross and Caswell. (Proc. Acad. Nat. Sci. Philadelphia, 1893, p. 176.)

‡ Op. cit, p. 232.

to be paralleled with those occurring in various parts of Europe and especially in southern Norway. For phonolites they are rather high in silica; thus an analysis of "Nordmarkite" or quartz syenite from Aueröd as quoted by Brögger* has a composition very similar but a greater amount of the ferromagnesian oxides in forming meta-silicates has left a little more silica than was necessary to turn the alkalies and alumina into feldspar and this excess appears as a minute amount of interstitial quartz; while in the present case as the amount of bivalent metals is very small there has not been sufficient silica to turn all the alkalies and alumina into feldspar and nephelite has thus been forced to form.

Another rock very similar to this has been furnished the writer by Prof. C. E. Beecher, who collected it at Deadwood in the summer of 1890. In regard to its occurrence Prof. Beecher says "it occurs as a vertical dike about fifty feet wide cutting through the schists and Paleozoic series in the mountain just south of Deadwood. The specimen was collected in the little ravine above the cemetery near the base of the mountain and where the dike cuts the Potsdam sandstone." The rock has a dense felsitic looking groundmass in which lie reddish *feldspar* phenocrysts, very thin tabular on $b(010)$ and often 1^{cm} across. They are not very numerous. Phenocrysts of a glittering black *hornblende* occur freely sprinkled through the rock. They are generally quite small, and needle-like but are sometimes stouter and attain a length of several m.m.

In thin section are seen in addition *apatite*, *titanite*, *pyroxene*, *nephelite*, *calcite* and zeolitic material. The feldspar is mostly sanidine in Carlsbad twins. A smaller amount of a striated feldspar occurs. The *hornblende* is very idiomorphic, often twinned on $a(100)$ and has the following pleochroism: $\mathfrak{a}$ light brownish yellow. $\mathfrak{b}$ olive brown, $\mathfrak{c}$ olive green, with absorption $\mathfrak{c} = \mathfrak{b} > \mathfrak{a}$. The angle $c \wedge \mathfrak{c}$ is about 12° and the double refraction is weak. A crystal extracted from the rock was found to have the forms $m(110)$, $a(100)$, $b(010)$ and $r(011)$ and to be twinned on $a(100)$. The prism $m(110)$ is largely developed, the pinacoids being very narrow. On the reflecting goniometer $m \wedge m$ $(110 \wedge 1\bar{1}0)$ was measured and found 55° 45′. Before the blowpipe the mineral fuses easily to a black shining magnetic globule coloring the flame strongly and persistently yellow—thus indicating the soda-iron molecule to be largely present. From these facts it would seem to approach most nearly to *barkevikite*, differing somewhat in pleochroism. There is also a gray green augite present in the rock in much smaller amount, which is generally greatly decomposed—limonite and calcite having formed at its expense.

* Min. der Syen. peg. gänge. Zeit. für Kryst., vol. xvi, p. 57, 1889.

These minerals lie in a *groundmass* of trachytic structure consisting mainly of singly twinned feldspars between which lie patches of a colorless mineral of very low single and double refraction which is assumed to be nephelite. Also shreds and fibers of ægirine and the hornblende just mentioned are present. The rock is considerably altered and for that reason no analysis is given. It effervesces considerably in acid and gelatinizes readily.

A rock from this region has been supplied to European dealers by the specimen dealers in Deadwood. The exact locality is unknown—the labels reading simply "Black Hills," but it is probably from the northern part of the region. It is sold under the name of "Tinguaite." The hand-specimen shows a splintery fracture and is of bright green color with a grayish cast and the rock strongly resembles some of the varieties of the acmite trachyte from the Crazy Mts. already mentioned. The grain is dense and an occasional long columnar augite is the only phenocryst to be seen.

In thin section it is seen to consist chiefly of a singly twinned feldspar arranged in trachytic structure with an occasional patch of nephelite. It is everywhere penetrated by a fine interminable mesh of ægirine rods and needles which sink to trichites in dimensions. While the feldspars are arranged in flow structure these ægirine needles are scattered without orientation, pass through and through the smallest feldspars and penetrate to some distance the larger ones. They particularly abound in the interspaces and with low powers give the section a peculiar mossy appearance. To them is due the green color of the rock. They are evidently a final product of consolidation, forming after the moving mass which had developed some augite phenocrysts and to a considerable extent the microlites of feldspar of its groundmass, had come to rest. The augite phenocrysts are of ægirine-augite with a deep green mantle of ægirine. The rock appears quite fresh. It gelatinizes in acid. As the locality is unknown, no analysis is given.

From Caswell's report and from what has been shown in the foregoing it is evident that in the Black Hills region there is an extremely interesting series of high alkali-rocks, a fuller knowledge of whose mode of occurrence and petrographical and chemical relations would aid materially in solving for the region that most interesting problem in petrology which Judd has so aptly characterized in the term "petrographical provinces."

Laboratory of Mineralogy and Petrography,
Sheffield Scientific School, New Haven, Dec., 1893.

ART. XXXVII.—*The General Structure of the Main Axis of the Green Mountains;* by CHARLES LIVY WHITTLE.

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THE anticlinal nature of the main axis of the Green Mountains was first suggested by Adams in 1846.* In 1847 the elder Hitchcock published a section of Hoosac Mountain in Massachusetts representing the strata overturned to the west and in his opinion the structure of the main axis in Vermont was the same.† Zodack Thompson argued for a synclinal axis‡ and T. Sterry Hunt was of the same opinion.§ Edward Hitchcock in his Geology of Vermont represents the structure of the axis between the Rutland and Plymouth valleys, along the Central Vermont railroad as a simple anticline.‖ At the time this survey was made (1861) the subject of induced schistosity was in its infancy, and it is rather surprising that the stratigraphy worked out so largely on the basis of schistosity alone should so nearly approximate to the real attitude of the very varied terranes that make up the area of the Green Mountains. Hitchcock's section VI, twenty miles north of section V, makes the gneiss dip uniformly east. Although along these lines the gneiss is represented as having a simple structure the text mentions that there are many minor irregularities and curvings in the stratification especially along the southern line near the town of Mt. Holly. The method then prosecuted of making geological maps by crossing the state once in so many miles, making observations on strike and dip where possible, accounts in part for the disagreement in the interpretation of the structure along the two lines mentioned.

My own observations in Vermont made mainly during three field seasons extended north and south along the highest portions of the Green Mountains from Chittenden on the north to Stratton on the south, and defined on the east and west by Windsor and Rutland valleys.

This area comprises part of the stretch of country embraced by sections V and VI above mentioned in Rutland and Windsor Counties.

*Second Annual Report on the Geology of Vermont. Adams. 1846, pp. 167 and 168.

† Elementary Geology. E. Hitchcock. 1847, p. 36 and 37.

‡ Address on the Natural History of Vermont. Preliminary Report on the Natural History of Vermont. Augustus Young. 1856. App. 6, pp. 65–68.

§ On Some Points in the Geology of Vermont. This Journal, vol. xlvi, 1868, p. 229.

‖ See vol. ii, Sec. V, 1861, and text giving description of this section, pp. 624–628.

Lower Cambrian quartzite and limestone occupy the Rutland valley. The quartzite lies at the base and is next above the series of metamorphosed clastics lying between it and the still more metamorphosed core of the range.* Plymouth valley is also occupied by limestone which extends north to North Sherburne, but its age is undetermined. Field evidence points strongly to its equivalence to one of the limestones in the metamorphosed clastics mentioned above occurring on the west side of the range.

The rocks of the range below the Olenellus horizon seem to fall into two groups. 1, a border series consisting alone, so far as I am aware, of metamorphosed sediments; and 2, a core series more metamorphosed, differing lithologically and carrying igneous rocks antedating the border series. When one first visits the eastern or western border of this area he is at once struck by the great variety of rocks and the apparent simplicity of their structure. Throughout the border areas the strike of the most prominent structure is commonly N. 10°–15° E. (magnetic) and the dip is generally steep easterly. This strike, as is now well known corresponds to the trend of the main Appalachian folding in New England. Further study of the rocks shows its secondary nature, traversing as it does rocks of the most varied texture and composition regardless of the real stratification, now usually not decipherable, but in many places still present where it has escaped the destructive dynamic action to which the rocks have been not only once but several times subjected. It is easy to be misled by this lamination and it soon became apparent that where the structure seemed the simplest in reality the obliteration of old bedding planes is the most complete. One of the best examples of this is seen at East Clarendon just north of where the Central Vermont railroad enters Mill River valley after leaving the Rutland valley. Here the rock, a metamorphic conglomerate in places is apparently as evenly-bedded as a Tertiary sandstone, but close inspection locally shows that most of the smaller pebble-like areas of quartz lying along the planes of schistosity are really sheared areas of quartz derived from genuine pebbles. The plane of shearing crosses the pebbles diagonally; by granulation of the several parts of the faulted clastics pseudo-pebbles lying parallel to the schistosity are produced which in cross section strongly resemble ordinary waterworn

* In a paper that will soon appear in the Journal of Geology on "The Occurrence of Algonkian Rocks in Vermont and the Evidence for their Sub-Division" the writer will call these upper metamorphic rocks the Mendon series. The Mendon series is thought to lie discordantly above a still more metamorphosed series in the core of the range that will be designated as the Mount Holly group.

pebbles. As a rule the attitude of the beds can only be determined at contacts between beds of strongly unlike composition, as between flinty quartzite and schist or limestone and some more resistant rock. Such contacts are relatively rare and a day's work in the most metamorphosed areas may not reward one with half a dozen indisputable observations on strike and dip.

The eastern and western borders are belts of near-shore deposits, now regarded as equivalent, of original coarse to fine conglomerates, sandstones and shales, which owing to their zone of deposition must have been persistent as a whole but locally the character would vary greatly. Such a belt, indurated and metamorphosed, has given rise to a series of more or less crystalline rocks which, owing to their extreme diversity of composition have resulted in schists and gneisses whose recognizable continuance of horizon is difficult to follow. Sections made east and west across their strike and one-half mile apart present a great diversity of character. The minor flutings of the more schistose members of this series illustrate on a small scale the larger folds of the main range. Along the western border the schists are bent into minute compressed puckerings commonly overturned to the west. These puckerings in turn compose much larger folds which in the same manner are overturned to the west. In a great many localities the folds and the smaller flutes are seen to accompany the inversion of the entire series; but in many places induced schistosity has so obliterated the stratification that the real attitude of the strata is not apparent, and in others no inversion of the strata as a whole has taken place. Throughout the core of the Green Mountain axis even a greater diversity of structure and rock exists. In the towns of Shrewsbury and Mt. Holly and extending southward the folding and shearing and consequent metamorphism are so great that final and satisfactory decipherment seems hopeless. Days may be spent without obtaining observations that would be of service in unravelling the tangle of gneisses and schists. As suggested to me by Mr. Pumpelly, platting all areas of like lithological character may give us the key to the structure, but this plan is rendered hazardous by the infinite variety of rock phase occurring making necessary grouping of areas of rock now so unlike that, in the present state of our knowledge a correlation of them would be of doubtful value. In the towns of Mt. Holly, Shrewsbury, Wallingford and the western part of Ludlow, there are areas of amphibolite now possessing a thoroughly schistose habit. At Summit station a railroad cut traverses this rock for nearly half a mile. Numerous separate members can still be distinguished in the pass by textual variations.

The amphibolites are cut by dikes of the same rock and also by more modern dikes of camptonite that are younger than the shearing. Such a series of amphibolites probably represents a period of volcanic activity vastly older than the Cambrian and of greater areal distribution than occurs at present. Further south, reconnoissance work has not detected them; they may have been eroded, while to the north, if they exist they are covered, except in two isolated localities by the sedimentary series lying immediately below the lower-Cambrian quartzite. Mr. Wolff has described an amphibolite from a hill situated about one mile south of Mt. Holly station and it is referred with probability to an original diabase by him in his forthcoming monograph on the Geology of Hoosac Mountain.* As mentioned above, dikes of the same rock traverse the amphibolites and possess the same local schistosity. There are many other areas of this rock in the region some of which are undoubtedly dikes, others owing to their extent are considered to be intrusives or surface flows. Their abundance may be cited as evidence of surface flows since it is improbable that any area, reasoning from analogy, would be traversed by so large a number of intrusives. This view is also sustained by the fact that diabases are prevailingly surface flows, such regions as Connecticut, New Jersey, and Keweenaw Point being examples. It may also be mentioned in this connection that in the border series of clastics I have observed no amphibolites. Diabases of any age are rare in Vermont and one would expect that were the amphibolites originally intrusive (assuming that the border series is not separated from the core by an unconformability) that similar areas would occur in rock stratigraphically higher than those under consideration. Below the associated rocks are referred to the Algonkian. As the Keweenawan with its abundance of surface volcanic rocks was presumably laid down near the close of the Algonkian time it is not unlikely that similar associated flows took place in the Algonkian rocks of Vermont.

Following the classification of pre-Cambrian rocks now adopted in this country none of this area studied in Vermont can be referred to the Archæan and must be placed in the Algonkian. The lowest rocks exposed in Shrewsbury and Mt. Holly, although of extreme age and gnarled and crinkled into a hopelessly involved structure still in larger part reveal their sedimentary origin by associated beds of crystalline limestone, now altered in part to serpentine or amphibole, and scattered outcrops of quartzite. With these two rocks or their representatives are biotite, augen gneisses and schists, garnetiferous mica

* Part 3, Geology of the Green Mountains in Massachusetts by R. Pumpelly, J. E. Wolff, T. Nelson Dale and Bayard T. Putnam, submitted in 1889.

schists, etc., etc. The micro-structure of all the core rocks attest the pressure brought to bear upon them by the granulated condition of their quartz and feldspar constituents—a feature which is strongly contrasted with the less-sugared and more modern appearance of the border series. The rocks of this area are less schistose; biotite seems to replace muscovite or sericite of the border metamorphics; gneisses are more dominant and the border regional cleavage of N. 10°–15° E. is not nearly so pronounced. In place of this we find a more coarsely crystalline structure—the structure being due more to an apparent rearrangement of their mineral constituents than to a development of mica along planes of shearing. This banding is lacking in any uniformity of trend and is strongly at variance with the persistence observed in the direction of the schistosity of the border: east and west strikes of lamination are perhaps as frequently met with as those trending north and south, and the dips are equally variable.

The upper part of the Algonkian or border series affords evidence of at least two periods of orographic disturbance; microscopic data for this the writer outlined in a bulletin of the Geological Society of America.* This evidence is based on the development of ottrelite and albites in the metamorphic conglomerate. These minerals as they grew include the crushed quartz and feldspar mosaic resulting from an earlier period of environment produced in part by folding. In turn the ottrelite and albite are occasionally bent and fractured evidencing a second period of disturbance less violent than the first. Structurally we have stronger evidence furnished by a conglomerate gneiss at North Sherburne where an anticlinal axis trending about 25° west of north represents the first period of disturbance; a later one induced in the rock the regional schistosity of the range striking, as mentioned above N. 10°–15° E. Other periods of folding in this series have probably taken place but the data for their detection are not at hand. The lower rocks of the Mt. Holly-Shrewsbury area must have experienced even greater mutations. The greater granulation and lithological differences observed and character of the folding may be cited as evidence in support of such a belief.

Mr. Wolff describes a northerly pitch in the crystallines of the New Jersey Highlands† and I have observed with him the same pitch of the rocks of Hoosac Mountain. In general the minor folds of the Green Mountains in the area described above have the same gentle, northerly pitch. In a large way

* Some Dynamic and Metasomatic Phenomena in a Metamorphic Conglomerate in the Green Mountains, vol. iv, pp. 147–166.

† "The Hibernian Fold," read before the Geological Society of America at the winter meeting held in Boston, Mass., in December, 1893.

the V-shaped area of pre-Cambrian rocks mapped by Hitchcock, occurring along the trend of the range indicates a falling away of the axis to the north.

Section VI of Hitchcock passes through Mendon and Sherburne where the border rocks are exposed capping the summits of the highest peaks, furnishing a key to the structure along this line where most of the detailed work has been done. As a working hypothesis the following sequence of metamorphosed clastics, exposed in continuous section on the west slope of Blue Ridge Mountain making the border series, has afforded positive results in deciphering Green Mountain structure: descending geologically from the base of the Olenellus quartzite the next rock is a bed of chloritic mica schist* very much crumpled, hence its thickness is difficult to obtain. It seems always to be present in this part of the State, although on Clarksburg Mountain in Massachusetts, lower Cambrian quartzite lies directly upon granitoid gneiss without any clastic series intervening. The question of the relationship between the mica schist and the Olenellus horizon will not be discussed at this time. In Vermont the mica schist at a minimum has a thickness of not more than fifty feet and in places it is certainly five hundred feet in thickness and may reach a thousand feet. Below the schist comes in several hundred feet of micaceous quartzite locally assuming a schistose phase, or on the other hand becoming massive and compact. All phases carry numerous pebbles of orthoclase, microcline and quartz, feldspar being most abundant. The quartzite horizon also varies greatly in thickness and may thin out entirely. Due east of Rutland a micaceous phase probably attains a thickness of four hundred feet. Next below is a white crystalline limestone, carrying the same varieties of pebbles, some phlogopite secondarily developed, and graphite. It locally thins out first passing through micaceous phases. In places areas have escaped recrystallization and are still blue in color, promising with careful search to yield fossils. Two hundred feet may be postulated as its maximum observed thickness in the heart of the range. Another thin bed of micaceous quartzite occurs below this containing one or more beds of interstratified limestones ten or fifteen feet in thickness. These lie upon the lowest member of the border series, the metamorphic conglomerate horizon which is separated from the

* Dana has used the name hydro-mica schist for similar rocks occurring in Massachusetts. Although it seems for many reasons the best name that has yet been proposed it does not seem generally to have been adopted. Microscopically the schist is composed mainly of chlorite and muscovite with varying proportions of sericite and biotite; quartz is nearly always present, but in extremely fissile phases it is practically absent. On the other hand varieties occur in which the micaceous constituent is much less in quantity.

lower rocks by no line of demarcation whatever—the two formations possessing an induced structural conformity due to dynamic processes. This conglomerate is by no means invariable in character, but is subject to great differences of habit. Normally it may be described as a conglomerate-gneiss in which more or less detrital material can still be seen. Its clastic character may be entirely lost when it passes into a chlorite, muscovite schist or when it is represented by a vitreous quartzite or quartzite breccia. I have previously described an ottrelite-bearing phase of this horizon.* It forms with the mica schist the most persistent horizon in the pre-Cambrian rocks known to me.

This border series has been extended eastward nearly continuously across the range to the Plymouth valley. A schistose phase of the metamorphic conglomerate forms the summit of Mendon and Killington, two of the highest peaks in the State. Blue Ridge is capped by the same rock and the beautiful mountain known as Pico is also surmounted by the same horizon overturned to the west upon the pebbly limestones. The limestones having been eaten out on the west and southwest undermining of the schist has taken place resulting in steep escarpments near the summit. In a general way this is true of many of the mountains in the heart of the range that have been examined by me north of Mt. Stratton. The eastern slopes are commonly much less steep than the western as would be the case were the strata really dipping towards the east and no doubt the topography is directly dependant on the eastward-dipping schistosity. But it is noticable that it is not the general schistosity that determines the positions of mountain crests but a somewhat local one of more pronounced character developed in the backs (east side) of overturned folds where, owing to greater shearing and stretching the maximum schistosity is developed, resulting in a belt of greatest resistance to erosion. The schistosity planes on the backs of the folds have a gentle dip easterly and consequently these slopes are comparatively gentle; the western slopes are often structurally infolded synclinal troughs in which by the reversal of the geological series the limestone belts occur with lower members above them. Whatever member of the metamorphic series now occupies the eastern or gentle slope of the mountains it is uniformly schistose. Ascending any of the high peaks in Mendon or Sherburne from the west one encounters steep slopes and usually a duplication of the infolded members of the series. In such environment crinkling and crushing are most pronounced,—the strata making the eastern slopes being much less crinkled

* An Ottrelite-Bearing Phase of a Metamorphic Conglomerate in the Green Mountains. This Journal, vol. xliv, 1892.

and more laminated,—and duplication of beds is very evident. One often meets the same infolded limestone bed three times on the steep western slopes of the mountains. The topography is seen to be genetically dependant upon the enforced schistosity while the stratigraphy exercises but little controlling influence. Steep westerly slopes, however, are in part due to the less resistant limestones in the troughs which, as on Pico undermine the more resistent rocks and give rise to pronounced escarpments. On a large scale Green Mountain folding is a parallel of the minute plications so often observed in the crenulated schists; a vertical line would often penetrate the same bed several times. As a result of sharp over-turning, thrusts probably occur but where metamorphism is so great it is doubtful if they can be detected in many cases.

A measure of the stretching and consequent thinning of the strata on the backs of folds is frequently found in the effect produced on pebbles in the quartzite or upon secondarily-developed tourmalines. Pebbles of feldspar having an original diameter of a quarter of an inch are now found drawn out to four inches; crystals of tourmaline which one may fairly assume were not more than one inch in diameter are now seen as linear films over a foot in length. Stretching of so pronounced a character as this takes place commonly along zones; belts of slipping in quartzite are frequently met where the surfaces for several hundred feet are ridged in parallel lines as though the quartzite were pulled out in the same manner that the confectioner stretches some varieties of confectionery when partly chilled. Compensation is not always made in this way; in some localities minute faulting takes its place. It is noticed that in the lower rocks the strain is often relieved in this manner. Lower coarse gneisses, for example, have not infrequently hundreds of minute faults to the square foot; along each of these fault planes, films of sericite are developed giving the weathered rock a reticulated appearance. Such faulting might suggest normal brecciation, but there is only slight displacement not attended by crushing and consequent destruction of the angularity of the faulted areas. Zones of this character were probably too far below the surface to be caught in the more superficial belt of crinkling and stretching, but underwent great pressure under enormous load giving rise to the observed faults, or the rocks suffered the faulting before the border rocks were deposited. The last explanation is regarded as much the most probable.

The structure of the main axis of the Green Mountains is thus seen to be a series of sharp, compressed folds striking approximately north and south and overturned to the west in most localities so that induced schistosity and stratification dip

eastward. Localities on the western border have a steep westerly dip in many instances; in others the border series as a whole is nearly in a vertical position. Many areas occur along this belt where the series is overturned to the west, but the exact angle at which the strata lie is difficult of determination. The orographic thrust producing the folding was directed nearly from the east and west. Normal faults and overthrusts are indicated but data for their detection is not now at hand except in one instance.

Cambridge, Mass., January 10, 1894.

Art. XXXVIII.—*Notes on Apparatus for the Geological Laboratory;* by J. E. Wolff.

The utility of the following methods and apparatus having been established by laboratory practice a brief description of them may be of benefit to others, a familiarity with the usual methods being assumed.

Diamond Saws.

These are made in the laboratory as follows: Disks of ordinary sheet tin are procured from a tinsmith, 6 inches in diameter, with a central hole $\frac{5}{8}$ inch in diameter to fit the arbor of the lathe. Two round wooden blocks are turned out from board, about $5\frac{1}{2}$ inches in diameter, and a central hole of the same size as that of the disk bored in one, while a corresponding round wooden stick is set into the center of the other. The tin disk is then placed between the two blocks, the round stick holding it central, and the whole fastened in a vise. The edge of the disk projecting beyond the wood is then notched by a shoemaker's knife which is held against it and struck a sharp blow with a light stick, but the plane of the knife is held slanting or oblique to the plane of the disk and not transverse, and moreover is inclined on opposite sides in adjacent quadrants. The notches are made as close together as possible without breaking the tin and about $\frac{1}{10}$ inch deep. The bort (preferably the so-called scrap carbon left as waste from diamond drills) is pulverized in a diamond mortar to a fine sand, corresponding nearly to grade 100 in corundum or emery powder, mixed with a little oil to form a stiff paste and inserted between the teeth of the saw by a pointed match. The edge is then gently hammered back to a plane, using a light hammer on an anvil, and the saw then turned over and hammered smooth on the other side. It requires one carat of bort to

charge a saw properly. By this method, which has been perfected in the laboratory by Mr. C. L. Whittle, the bort is forced into the tin and held fast by the teeth, which owing to the oblique cutting of the notches press tightly together when hammered back to place. The teeth are cut obliquely on opposite sides in adjoining quadrants in order to distribute the bort equally on both sides of the saw. A refinement on the notching process described above consists in the use of a brass disk with guide notches cut into its edge, by which the knife can be guided and the notches made evenly.

Saws thus made will do a surprising amount of work before wearing out. In two cases, where a record was kept, the saws cut respectively 300 and 400 square inches of rock, mainly of crystalline varieties.

Method of sawing sections thin.—Power is furnished for the laboratory from a 5 H. P. electric motor which is run from a street current (500 volts) but only 2 H. P. of current is used and paid for as this suffices for the lathes and electric light. For grinding rock surfaces the usual revolving zinc and iron plates are used with three machines, for coarse, medium and fine emery or corundum (Nos. 60, 80, and F.F.F.). The diamond saw, placed in an ordinary lathe, revolves at a speed of 600 to 700 revolutions per minute in the narrow slit of a brass platform on which an adjustable gauge slides in a groove at right angles to the saw, with a pivot and clamp so as to allow the adjustment to exact parallelism between its face and the plane of the saw. The piece of rock, sawed and polished on one side, is cemented to a square piece of thick glass but little larger than the specimen. The cementing substance used is a mixture of Venetian turpentine and shellac boiled down to the proper consistency. White shellac is preferable to brown on account of the increased transparency but the white stick shellac is often impure and refuses to melt, hence it is best to use liquid white shellac. The tenacity of this mixture is greater than that of Canada balsam and when white shellac is used may often be left under the section when finally mounted. The glass, with the specimen attached, is put against the gauge which is then moved close to the saw so that it almost touches the glass at the base of the specimen and is also adjusted to parallelism. The saw is then started and gently pressed against the glass while the longest side of the specimen is presented to the cutting edge; as the saw cuts in, the glass is slowly turned around while pressed against the gauge, until a cut is made completely around the specimen, when the central part is cut through and the slide removed. Where many persons use the same machine, it is impossible to keep saw and gauge in permanent adjustment, but after adjusting them to

parallelism by eye, the precaution of turning the slide will generally keep the saw from cutting through the specimen into the glass. The saw must be kept wet by dropping water or by a sponge. When it is stated that slices have been sawed in the laboratory from $\frac{1}{600}$ to $\frac{1}{1800}$ of an inch thick it will be plain how easily this accident may happen without precautions, but that when successful this method saves much time and labor in attaining the ultimate thickness (about $\frac{1}{800}$ inch).

The Arc Light for Projection.

In microscopic projection, especially with high powers and polarized light, the lime-light is insufficient for a projection of any size, while with the arc light, objectives of 4^{mm} focus and less can be used. The following arrangements are made in the laboratory for this purpose.

A 1 Kilowatt dynamo, requiring about $1\frac{1}{2}$ H. P., is run by a belt from the motor in the basement and the current carried to two lecture rooms above. At full load the dynamo gives 18 to 21 amperes current at 55 volts, while by varying the load and regulating the current to the fields, from 80 to 0 volts can be obtained. For microscopic projection a large Zeiss microphotographic apparatus was available, but any petrographical microscope with condenser and water chamber can be used with a suitable arc lamp. Special projecting microscopes such as those made by Newton & Co., London, are said to give excellent results. We use the Schuckert projection lamp which belongs with the Zeiss apparatus, in which the carbons are inclined so that the crater of the positive carbon radiates the light to the condenser. The lamp is adjusted for 45 volts 16 amperes but runs perfectly with 50 volts and 19 or 20 amperes giving from 2500 to 3000 c. p. It is perfectly steady and self-regulating, so that when once started it burns without attention. It can be run with least trouble from a storage battery of 25 to 30 cells, thus avoiding inequalities of current due to the running of the dynamo. The imported carbons cost about 5¢ a pair and burn two or three hours. A variable German silver wire resistance with sliding contact is introduced into the circuit near the lamp, so as to give some control over the current in case of variation in speed of the dynamo. A switch throws the same current into 20 incandescent lights for lighting the room when the arc is not in use. With this arrangement projections of rock slides in polarized light are shown to the class in illustration of the lectures. The screen, which consists of a plaster surface cast on plate-glass and mounted in a frame, stands at 12 feet from the microscope and the projections are then about 2 ft. 6 in. in diameter, cor-

responding to the diaphragm in the eye-piece, while with the objectives alone they are of course much larger. Objectives are used ranging from 3 inches to 4^{mm} focus; with the latter it is barely possible to make microfelsitic structure visible. The rings and brushes of crystals in converging polarized light and other facts of optical mineralogy are well shown. For the projection of ordinary lantern-slides the microscope is replaced by a projecting lens and slide holder and at this short distance the light is so powerful that the projections are visible by ordinary daylight, a great convenience in a continuous lecture. The arc-lamp is also used for this purpose in a large lecture-room with a great gain in amount of light and convenience over the oxyhydrogen light.

The lamp is also used for microphotography and is occasionally useful in other ways. The dynamo current, properly regulated can be used in place of the usual battery for exciting the electro magnet in the magnetic separation of the iron-bearing minerals of rocks, with the advantage of easy variation in the strength of the pull exerted.

Harvard University, Petrographical Laboratory, Feb., 1894.

Art. XXXIX.—*Diversity of the Glacial Drift along its Boundary;* by Warren Upham.*

Recency and probable Brevity of the Glacial period.—The recession of the ice-sheet at the end of the Glacial period in the northern United States and Canada and in Great Britain seems to have been separated from the present day by a Post-glacial or Recent epoch of only about 6,000 to 10,000 years, as made known by the observations and reasoning of N. H. Winchell, Gilbert, Andrews, Wright, Mackintosh, Prestwich, and others. This conclusion, and the uniqueness of the Ice age, standing quite alone as a strange episode of geologic history, unexampled besides in all the very long Cenozoic and Mesozoic eras, forbid our longer reliance upon the once generally accepted astronomic theory of Croll, Geikie, and Ball, that the accumulation of the ice sheets was due to terrestrial conditions springing from the earth's relations to the sun during a period of increased eccentricity of the earth's orbit from about 240,000 years to 80,000 years ago. Dr. Croll's theory supposed glacial epochs to recur alternately in the northern and southern hemispheres each 21,000 years during the astro-

* A paper presented before the Geological Society of America at the Boston meeting, Dec. 29, 1893.

nomic period mentioned, giving seven or eight epochs of glaciation and as many interglacial epochs when the ice-sheets were melted away; but continuous temperate conditions similar to those of the present would have prevailed during the past 50,000 years or more. The recency of the date marking the close of the Ice age is inconsistent with the astronomic theory. But under the fruitful incentive of that theory many glacialists in Europe and America have interpreted their observations as establishing the recurrence of glacial and interglacial epochs which it suggested; and some who distrust or reject astronomic causes for the Ice age continue to hold this interpretation of the records of the glacial drift.

Looking through the long past ages previous to the Pleistocene, we come to no time affording evidences of widely extended glaciation, probably affecting continental areas, till we pass back at least many million years. Only one earlier stage of the earth's changes was attended, so far as geology can tell us, with the envelopment of large land areas beneath ice-sheets, and this was in the Permian period, closing the Paleozoic era. It was a time of great orogenic and epeirogenic changes; and I think that then, as in the Pleistocene Ice age, the accumulation of thick sheets of land ice was due to great epeirogenic uplifts of those areas so high as to give them a cool climate and chiefly snowfall instead of rainfall throughout the year. If extensive glaciation has been so rare, shall we readily believe that during the geologically very short Quaternary or Psychozoic era there have been two or three or several Glacial epochs? More probably, as I think, we shall find all the diverse phases of our glacial drift referable to a single and continuous Ice age; and the very slight changes of marine molluscan faunas during this age implies its exceptional brevity in comparison with any of the preceding periods recognized by geologists.

Earlier and Later Drift near its boundaries in the Mississippi basin.—The admirable work of Profs. Chamberlin and Salisbury on the Wisconsin driftless area and farther south in the Mississippi basin discriminates earlier, mostly thin, and later, thick and morainic, varieties of the drift border. These differ widely in their volume of drift, in its constituent material, and in the times of its deposition. Along the greater part of the boundaries of the drift on those areas, it terminates in an attenuated border, slowly thinning out and presenting considerable difficulty for the recognition and mapping of its limits. Indeed, it is apt to occur on its outermost tracts in low and thin, smooth patches, more or less isolated, and these are thought to represent in large degree the original method of deposition, not being a result of subsequent erosion. These

drift deposits belong to the time of maximum ice advance, and are much earlier than the marginal moraines of thick and irregularly knolly and hilly drift which were accumulated when the ice-sheet terminated farther north. There was, however, in some districts, as Mr. Frank Leverett has found in Illinois, a special massing of the early drift upon a belt near its boundary. In general the drift border is attenuated, but occasionally its thickness in the outermost five miles attains a maximum of 50 feet; and several times as much drift is found on that belt as in the adjacent drift-bearing belt 5 to 20 miles farther back within the glaciated area.

In this great region of smoothly spread early till, comprising large expanses on both sides of the Mississippi River, there was very scanty glacial erosion of the bed rocks. An area of 16,500 square miles in northeastern Iowa, according to McGee, has nearly everywhere a small thickness of the preglacial residuary clay and decaying rock still remaining beneath the universal mantle of the drift, which is principally till, the product of an overriding ice-sheet. McGee further notes that nearly all of the bowlders and smaller rock fragments of that till in both its lower and upper deposits, and by inference also its finer sandy and clayey matrix, were derived from formations lying north of the limits of Iowa. Bringing much drift, the ice-sheet twice advanced upon this area. Its first advance did not erode even so much as the thin preglacial residuary products of secular rock decay and denudation, which are found to average about seven feet in depth on the adjacent Wisconsin driftless area. Between the two ice incursions a forest grew on the land, and its fallen trees and peaty swamps were left upon many townships almost intact, as is known by the forest beds found in digging wells, while the later ice advance covered them with a second sheet of till, which is mostly from 3 or 5 to 10 or 20 feet thick and in some places is probably as much as 80 feet thick.

The feeble eroding action of the ice-sheets depositing the smooth expanses of the outer and earlier drift is remarkably contrasted with the vigor of erosion displayed by the planed and striated rock surface of the areas enclosed by the later marginal moraines. When the ice-sheets heaped these morainic hills it wore into its adjacent rock bed and accomplished much rock erosion upon all the region of the later and uneven drift, which encloses lakes and lakelets, reaching northward from the outermost large and continuous moraine and covering the far greater part of our drift-bearing area.

Portions of the Drift Border formed by Marginal Moraines of the Later Drift adjoining the Wisconsin Driftless Area and in the eastern United States.—Along a distance of

about 80 miles on the east side of the driftless area in Wisconsin the magnificently developed Kettle moraine, belonging to a late part of the Ice age, forms the extreme border of the drift. Its correlation or continuation in Minnesota, Iowa, and South and North Dakota, is probably the Altamont moraine, the outermost of the series of twelve approximately parallel successive retreatal moraines which I have explored and mapped, under the direction of Prof. N. H. Winchell, for the Minnesota Geological Survey. Near Des Moines in central Iowa this Altamont or first moraine of the Minnesota series, there forming the southern extremity of an area of the later drift deposited by the Minnesota and Iowa lobe of the ice-sheet, lies 175 miles north of the southern boundary of the drift in its course through Missouri and northeastern Kansas. Within the Mississippi basin the ice sheet forming the Kettle and Altamont moraines occupied less area by 125,000 square miles than was enveloped by the ice forming the earlier drift. But while there had been in general this great decrease in the extent of the ice previous to the accumulation of the outer large moraine, it even advanced at that time farther than ever before upon the east side of the Wisconsin driftless area.

In the eastern United States, the outer moraine along an extent of about 700 miles, from the Scioto basin in Ohio to Martha's Vineyard and Nantucket, stands upon the boundary of the drift or very near it. At its time of maximum extension the ice-sheet in this region generally reached a short distance, from a few miles up to twenty miles or more, beyond the position of the moraine. Besides this remarkable difference from the drift of the Mississippi basin, it must be confessed that we cannot yet be sure that this outer moraine, at least eastward from the angle of the drift boundary in southwestern New York, is to be correlated with the Kettle and Altamont belt. Following a suggestion or query of Mr. Leverett, I incline to believe that quite as likely it may belong somewhere within the time of the very large Fergus Falls, Leaf Hills, and Itasca moraines, which are the eighth, ninth and tenth of the series in Minnesota.

Oscillations of the Boundary and Changes in the Thickness and Currents of the Ice-sheet during its general Recession.—The great contrast between the glacial retreat from northeastern Kansas to Des Moines and the contemporaneous encroachment of the ice upon the eastern side of the Wisconsin driftless area seems to be accounted for, in part or wholly, by interdependence of snowfall at the east with rains and ice melting at the west. While the ice was being melted away by rains and sunshine over its 125,000 square miles that had been uncovered south and west of central Wisconsin, the east-

wardly moving air currents, abundantly laden with moisture from that region, were chilled in their farther progress over the ice-sheet north and east of the driftless area, and there gave exceptionally heavy snowfalls, permitting that part of the ice-sheet to grow thick and high, with only slight recession. At last, when there came a temporary general reversal of the warm climate under which the ice-sheet had been mainly retreating, its halt or re-advance producing the first of the prominent moraines carried the ice-front in Wisconsin forward upon a part of the area which previously had no drift.

During the great recession of the ice in the Mississippi basin, it probably withdrew much less, perhaps mostly from ten to thirty or forty miles, in Ohio, Pennsylvania, northern New Jersey, and Long Island, and south of Rhode Island and eastern Massachusetts. Meanwhile, as in eastern Wisconsin, it had grown thicker than during its time of maximum area, and the sudden and short climatic changes leading to the formation of the moraines allowed the ice in the eastern states to flow out again almost to its earlier limit, and in some places even beyond it. Considering how nearly coincident the earlier and later drift boundaries are for this long distance from the Scioto River in Ohio eastward, we naturally feel much reluctance against referring them to distinct epochs of glaciation separated by a long interglacial time, as some have supposed, when the ice-sheet made a long retreat to the north or was wholly melted as now from this continent. It seems to me more reasonable to appeal, as Prof. James D. Dana has recently done,* to meteorological differences between the Mississippi basin and the eastern states, whereby comparatively long glacial retreats and re-advances could take place at the west while in the east the ice-border more steadily remained near the drift boundary.

What shall be said, consistent with this view, concerning the extra-morainic drift in New Jersey, some of which occurs more markedly in isolated patches than any of the early drift before noted in the Mississippi basin? Prof. Salisbury estimates that a very long time of ordinary subaërial erosion intervened between the times of deposition of the earlier and later drift in New Jersey, so that the denudation of the land had removed the greater part of the earlier drift, leaving only its present patches on the extreme boundary, before the late moraine-producing ice advance. If this is a needful explanation, it goes far toward establishing a longer and probably more complex history of the Ice age than the view taken in this essay. It seems to me, however, that the manner of transportation and deposition of that early drift may explain its

* This Journal, III, vol. xlvi, pp. 327–330, Nov., 1893.

uneven distribution. The early accumulation and advance of the ice to its extreme limits gave a comparatively thin ice-sheet with feeble erosive action on all the outer part of the drift-bearing area. Its drift there was nearly all brought from considerable distances at the north and was deposited in obedience to the glacial currents of the marginal portions of the ice-sheet. Now we have upon many districts of the thick later drift the remarkable aggregations of the till called drumlins, which appear to have been amassed by convergent currents of the ice-sheet during its retreat.* Similar selective action of the outflowing early ice advance close to its farthest limits I think to have amassed that outermost early till in the patches where it is now found, having received little change by later erosion.

The well oxidized and leached condition of the early outer drift everywhere is easily referred to its derivation chiefly from the preglacial residuary clays, decaying rocks, weathered rock cliffs and tors, and bowlders of secular disintegration. Again, its smoothed surface, without the inequalities of accumulation which provide basins for the myriad lakes and lakelets of the later drift, seems attributable to the gentle currents of the early thin ice-sheet, in contrast with which the late thick ice powerfully eroded its rock bed, even close to the boundary, and tumultuously heaped or very irregularly spread its drift with many lake-enclosing hollows.

Forest beds between deposits of till in northeastern Iowa, and in portions of other states of the Mississippi basin, testify of glacial recessions and re-advances, the ice-sheet probably recovering at some times marginal belts from 50 to 100 or 200 miles wide of its previously lost ground. These great oscillations, however, need not have required a very long time, certainly no more than a few thousand years for them all, as we may well learn from Prof. I. C. Russell's observations of the drift-enveloped and forest-clad borders of the Malaspina ice-sheet between Mt. St. Elias and the ocean.

Amid the waverings of the retreating ice, often large channels were cut in the early drift and became covered and partially filled by the later drift. In southern Minnesota these old water-courses are recognized as far northward as the Minnesota river valley, considerably to the north of all our recorded observations of forest and peat beds enclosed in the till sheet. They seem to have been probably rapidly eroded when the altitude of the country and its slopes of descent from north to south were greater than now. The few thousand years which are here regarded as the time of the fluctua-

* "Conditions of Accumulation of Drumlins," Am. Geologist, vol. x, pp. 339–362, Dec., 1892.

tions of the ice-front recorded by the forest beds appear to be ample for the attendant stream channelling.

Farther northward, along the 700 miles of length of the glacial lake Agassiz the retreat of the ice-sheet, with the formation of numerous large moraines, was demonstrably very rapid, occupying apparently no more than one thousand years.* In all, I believe that a duration of five thousand years is sufficient to account for the records of the waning and closing stages of the Ice age, from the time of the maximum area of the ice-sheet depositing the early drift to the time when Lake Agassiz was drawn off into Hudson Bay and the northern United States and Canada were freed from their glacial mantle and occupied by hunting and fishing tribes of the red race, who have abode here with many intertribal wars and migrations during the 5,000 years or more since the departure of the ice. A very large part of my belief that these oscillations and important changes of the currents of the ice-sheet during its recession were comprised within a time geologically so short, comes from my studies of the shore erosion and beach accumulations of Lake Agassiz, and of great changes in the relations of the northeastern and northwestern convergent ice-currents in Minnesota during the deposition of the later drift.† These, I am convinced, took place fast, in a geological sense, and I am persuaded also that the ice oscillations and varying conditions causing the diversity of the drift near its boundaries were not of great duration and are referable to a continuous and brief Ice age, not divided by interglacial epochs.

Loess deposition mainly continuous from the time of maximum ice extension to the time of formation of the Moraines of the Later Drift.—On the drift border in southern Illinois and Indiana, Prof. R. D. Salisbury finds that the deposition of the loess ensued immediately after that of the early till and was in part contemporaneous with the till. As soon as the ice-sheet retired from its farthest limit the glacial drift was covered by this fine silt of the modified drift supplied by streams that flowed from the melting and retreating ice.‡

In the northeastern part of Iowa Mr. W J McGee similarly finds the loess to have been deposited while the ice-sheet that spread the upper portion of the early till was melting away. The very remarkable paha of that district, which are eskers of loess, were accumulated while the waning ice-sheet walled them in on each side.§

* Geol. and Nat. Hist. Survey of Canada, An. Rep., new series, vol. iv, for 1888–'89, pp. 50, 51E.

† Proc. A. A. A. S., vol. xxxii, for 1883, pp. 231–234.

‡ Geol. Survey of Arkansas, Ann. Rep. for 1889, vol. ii, "The Geology of Crowley's Ridge" (1891), pp. 228, 229.

§ U. S. Geol. Survey, Eleventh An. Rep., for 1889–'90, pp. 435–471.

That the later part of the loess deposition was contemporaneous with the formation of the prominent Altamont moraine of the later drift, I ascertained in northwestern Iowa, where this moraine along a distance of 75 miles, from Guthrie County northwestward to Storm Lake, is bordered on its west side by an expanse of loess as high as the crests of the morainic hills, while its elevation above the expanse of till eastward is from 50 to 75 feet. During the time of deposition of this part of the loess the ice-sheet reached to the Altamont moraine and was a barrier preventing the waters by which the loess was brought from flowing over the lower area of till that reaches thence east to the Des Moines river.*

These observations in three widely separated regions prove that the loess, like the coarser portions of the modified drift forming sand and gravel plains, was in progress of deposition upon successive areas as fast as the ice-sheet supplying these stratified drift beds receded. Immediately after the land was bared by the retreat of the ice, and even while the ice itself occupied the adjoining land, the loess was being laid down, contemporaneous successively with the earliest till on the southern limit of the drift, with the till of intermediate age in northeastern Iowa, and with the later till enclosed by the Altamont moraine.

Such being the well demonstrated origin of the loess and its relations with the earlier and later glacial drift, it seems impossible that the rock gorges described by Mr. Oscar H. Hershey upon the area of the early drift in northwestern Illinois can have been eroded, as he supposes, between the times of deposition of the drift and of the loess.† Instead, I think that the early drift there and its closely ensuing loess so filled the valleys and raised the streams above the beds of the deep preglacial channels that in the places noted by Mr. Hershey the streams were turned aside into preglacial courses of small tributaries or across cols of plateau tracts which had become isolated alongside the valleys by the processes of ordinary land erosion and general weathering with rain, rill, and stream sculpture. This view brings harmony with Prof. Salisbury's assignment of the loess upon the early drift region to a time contemporaneous with the retirement of the ice-sheet from its farthest boundaries.

* Geol. and Nat. Hist. Survey of Minnesota, Ninth An. Rep. for 1880, pp. 307–314, 338.

† Am. Geologist, vol. xii, pp. 314–323, Nov., 1893.

Art. XL.—*An Elementary Expression in Thermo-electrics;* by Carl Barus.

1. The thermo-electric equation due respectively to Avenarius* and to Tait,† does not reproduce the observations satisfactorily when long temperature ranges (>1000° C.) are dealt with.‡ Within an interval of a few hundred degrees, however, the equation is usually in good accord with the experimental results. It is desirable, therefore, to endeavor to find a more general relation, from which the Tait equation may be derived as an approximation. This is my object in the present paper. I have tried to throw some light on the subject without explicit reference either to the Peltier or to the Thomson effect, and in a deductively experimental way, as follows:

2. In an investigation of the relation between the thermo-electric power and the specific resistance of steel varying with hardness, Dr. Strouhal and I found a linear relation§ to obtain. Some 90 states of hardness were examined, all tempered with scrupulous care. I have since endeavored to test this relation further, by making as many different platinum alloys as I could (54 in all), but found‖ that marked changes of specific resistance (10–65 microhms) were as common, as marked changes of thermoelectric power were rare, and no law was apparent. Nevertheless I am unwilling to concede that the results for steel in their bearing on the subject in hand are devoid of suggestion; at least I believe that the relation which holds for temper will also hold for temperature because in the latter case the structure of the metal is to a less extent interfered with.

3. When long ranges of temperature are considered the relation of metallic resistance¶ to temperature is not such that its nature can be closely enough inferred, experimentally. Electrolytic resistance, however, presents a promising case. The thermal variation of the resistance of an electrolyte, as I found both in the case of aqueous solutions (zinc sulphate)

* Avenarius: Pogg. Ann., cxix, p. 406, 1863.

† Tait: Trans. R. S. Edinbgh., xxvii, p. 125, 1872–73.

‡ Prof. Tait does not claim that the formula will do so.

§ Wied. Ann., xi, p. 969 et seq., 1880. It will be remembered that the resistance of hard steel is 3 to 4 times as large as that of soft steel. Cf. Phil. Mag., (5), viii, p. 341, 1879.

‖ Barus: this Journal, xxxvi, p. 427, 1888; Bull. U. S. G. S., No. 54, pp. 143, 146, 1889.

¶ The striking results of Dewar and Fleming (Phil. Mag., xxxvi, p. 271, 1893), from which an absence of metallic resistance at the absolute zero of temperature may be inferred, are rather of the nature of an initial tangent to the curve above in question.

under pressure,* and in connection with the examination of rock magmas† made by Prof. J. P. Iddings and myself, can be reproduced by an elementary equation, $dr/d\theta = a - br$, where r denotes the resistance, θ the temperature, a and b are constants, and where a is probably introduced by observational errors.

4. Following out the suggestions of §§2, 3, I tested the elementary expression

$$de/d\theta = -Ae \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

where e may be called the thermoelectric *condition* of an element of length of either wire of the couple, at the temperature θ. A is a specific constant for the metal, and may be either positive or negative.

Let θ, θ_0 be the temperatures of the hot and the cold junction, and θ_n the neutral temperature of the two given wires. Let e_n be the thermoelectric condition of one of the wires at the neutral temperature θ_n. Then (1) leads to the integral

$$\frac{e}{e_n} = \varepsilon^{A(\theta_n - \theta)} \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

where ε is the base of Napier's logarithms. Hence if the two wires of the couple be distinguished by accents, the parts which the hot junction contributes to the total electromotive force E, will be

$$\frac{e}{e_n} = \varepsilon^{A(\theta - \theta)}, \text{ and } \frac{e'}{e'_n} = \varepsilon^{A'(\theta_n - \theta)};$$

and the cold function contributes,

$$\frac{e_0}{e_n} = \varepsilon^{A(\theta_n - \theta_0)}, \text{ and } \frac{e'_0}{e'_n} = \varepsilon^{A'(\theta - \theta_0)}.$$

Hence since the observed or total electromotive force is $E = e \pm e' - (e_0 \pm e'_0)$ in the most general case; and since $e_n = e'_n$ by definition, therefore

$$(3) \quad E = e_n \left\{ \varepsilon^{A(\theta_n - \theta)} \pm \varepsilon^{A'(\theta_n - \theta)} - \left(\varepsilon^{A(\theta_n - \theta_0)} \pm \varepsilon^{A'(\theta_n - \theta_0)} \right) \right\},$$

which is the equation required. With reference to (3) it is to be noted that A, A', θ_n, may be either positive or negative; hence the exponents may represent either a sum or a difference. Again if θ_m be the temperature at which E is a maximum or minimum, then

$$A\varepsilon^{A(\theta_n - \theta_m)} \pm A'\varepsilon^{A'(\theta_n - \theta_m)} = 0, \quad . \quad . \quad . \quad . \quad (4)$$

whence

$$\theta_m = \theta_n + \frac{\log A \pm \log A'}{A \pm A'}.$$

* This Journal, xlii, p. 134, 1891. † This Journal, xliv, pp. 242, 255, 1892.

5. Now to show that equation (3) contains Tait's equation as one of its approximate forms, suppose that in an expansion of the exponentials in (3), terms involving higher powers than the second can be rejected. Then (3) leads to

$$(5) \quad E=(\theta-\theta_0)\,(A^2 \pm A'^2)e_n \left\{ -\left(\frac{A \pm A'}{A^2 \pm A'^2}+\theta_n\right)+\frac{\theta+\theta_0}{2} \right\}$$

But for $dE/d\theta = 0$, $\theta = \theta_m$, and θ_m may therefore be found either by differentiating (5) or by expanding (4). Its value is

$$\theta_m = \theta_n + \frac{A \pm A'}{A^2 \pm A'^2} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (6)$$

Substituting (6) in (5),

$$(7) \quad . \quad . \quad . \quad . \quad E=(\theta-\theta_0)\,(A^2 \pm A'^2)e_n \left\{ -\theta_m+\frac{\theta+\theta_0}{2} \right\}.$$

Since $(A^2 \pm A'^2)e_n$ is constant for the given couple, and since θ_m for reasons already given, § 4, may be either positive or negative, equation (7) is identical with Tait's equation.

6. Now it is desirable to look somewhat more in detail at the physical meaning of the elementary equation (1). In my work* on the thermal variation of the viscosity, η, of a very viscous body like marine glue I found that the elementary equation $d\eta/d\theta = -B\eta$, where θ denotes temperature, very fully reproduced the results. But since by Maxwell's theory of viscosity, η is immediately dependent on the configurational stability of a body, the same is true of the rate $d\eta/d\theta$ at which viscosity varies with temperature. Again the result, mentioned in §3, put in the form $dr/d\theta = -br$ shows that like the resistance r, so also the rate $dr/d\theta$ at which resistance decreases with temperature is immediately dependent on the molecular stability of the electrolyte. An interesting research of Auerbach's† on the resistance and bulk density of a given metallic powder (silver) is particularly suggestive here. He finds $dr/d\delta = -nr$, where δ is the bulk density and n constant. Comparing this with the preceding equation, it is clear at once that the internal contacts are similarly increased in the two cases. I therefore infer finally that equation (1) is open to an analogous interpretation, viz: that the thermoelectric condition e of an element of length of the thermocouple is directly related to the molecular stability of the element. In other words two metals are thermoelectrically identical, when the sign and the number of *available* molecular paths which the current (or better the elementary charge) is free to take, is the

* Proceedings Am. Acad., xxvii, p. 13, 1892; this Journal, xlv, p. 87, 1893.
† Auerbach: Wied. Ann., xxviii, p. 609, 1886.

same in both metals; and they differ thermoelectrically when this is not the case. If the transfer of charges is brought about in essentially similar ways both in metals and in electrolytes,* it follows that the available paths of a charge must be in its immediate neighborhood.

Long ago Wild† pointed out that bad metallic conductors were apt to occupy extreme positions in the thermoelectric scale, relative to good conductors. An analogous but much more definite result was brought out strikingly in the investigations on tempered steel‡ already cited, §2. Indeed we found it expedient to refer all our thermoelectric data to an imaginary steel rod whose specific resistance is zero, and an independent consideration§ then showed that this rod would be nearly given by steel (better perhaps by iron) cooled down to the absolute zero of temperature.

7. A somewhat pictorial yet nevertheless interesting development of the preceding paragraphs is obtained as follows: From its mode of derivation, the thermoelectric condition, e, depends on the state of electric dissociation at the given point of the couple, for the given temperature. Hence it is conceivable that a current in the wire, and e, will at all points be reciprocally related. Indeed a serviceable mechanism for Peltier and the Thomson effects is apparently near at hand. To begin with the former: if the two wires of the couple are thermoelectrically active, then they cannot be at the same state of dissociation. If therefore a current crosses the junction, it passes suddenly from a wire in a lower state of dissociation (say) to one in a higher state; or in other words from a metal having relatively fewer available paths to one having relatively more available paths. The case is thus closely analogous to that of a fluid passing from a state of compression suddenly into a state of dilatation, whereby heat is absorbed because internal work is done. Conversely if the current pass from a metal in a more advanced state of dissociation to one in a lower state, the case is that of a liquid passing from greater to smaller bulk and heat is evolved. Here therefore is a tangible mechanism for the Peltier effect: for if it be admitted that electricity travels in definite charges, its condition in a given space must be quite as atomic‖ as the matter which transports it, and heat is therefore absorbed or given off in marked degree at the thermoelectric junction for much the same reasons that

* Cf. J. J. Thomson: Application of dynamics, etc., p. 296, and others.
† Wild: cf. Mousson Physik, III, 2d ed., p. 387.
‡ Barus and Strouhal: l. c., p. 62 et seq.
§ l. c., pp. 65, 92.
‖ v. Helmholtz commenting on Faraday's law: ". . . gerade so, als wäre die Elektricität selbst in Atome getheilt." Berliner Sitzungsberichte, 1883, p. 651.

may be brought forward in accounting for the thermal effects of the expansion of the metals themselves.

Again since in virtue of the character of e the same state of things must supervene at any section between parts of the same wire at different temperatures, a mechanism for the Thomson effect is also apparent and differs from that of the Peltier effect only in degree.

If the current passing through a thermoelectric junction be spoken of as having a certain sectional density or intensity in each of the wires, it is clear that this quantity need not vary from the first wire to the second. What has varied is the number and the internal or molecular distribution of the component paths. The postulated expansion is a configurational change within the fixed bulk of the wires. An example might be given of charges traveling bivalently in one metal and univalently in the other, though I do not wish to limit myself to such a case.

8. In the further pursuit of the subject it is advisable to proceed from a different point of view, by taking advantage of vant'Hoff's* conception of a solid solution. Seeing moreover that in a large and important class of thermo-couples (iridio-platinum and other platinum alloys, iron and steel, etc.) the metals consist of what may be regarded as two different states of concentration of the same alloy, Helmholtz's† results for "Concentrationsströme" are available, particularly in the form given in a remarkable paper by Nernst.‡ Eliminating the osmotic pressures in the usual way, an equation results in which the electromotive force of the couple is expressed in terms of the concentrations and of the velocities of the ions at the temperatures of the junctions together with those temperatures. The problem then consists in finding the conditions or approximations under which the equation reduces to Tait's form. I have carried this out obtaining results of a certain degree of interest but not enough so to make it worth while to reproduce the long computation here.

9. In closing the present paper I had hoped to make a test of equation (3) above, by the aid of data obtained in a direct comparison§ of the platinum-iridioplatinum couple with the air thermometer. Moreover as the corresponding electromotive forces of this couple and of platinum-rhodioplatinum, in

* vant'Hoff: Zeits. Phys. Chem., v, p. 322, 1890. Ideas of this kind seem to have originated with Matthiessen, cf. Rep. Br. Assoc. 1866, p. 15, and Bulletin U. S. G. S., No. 14, 1885.

† Helmholtz: Zur Thermodynamik chem. Vorgänge, Verh. d. Berliner Ak., July, 1882, p. 489.

‡ Nernst: Zeits. Phys. Chem., iv, p. 129, 1889.

§ Barus: Bull. U. S. Geolog. Survey, No. 54, p. 216 et seq., 1889; cf. Phil. Mag., July, 1892, p. 1.

their variations with temperature throughout an interval of nearly 2000° centigrade remain strictly linear functions* of each other, both may be reasonably looked upon as evidencing a clearly pronounced thermoelectric law. However, in the absence of a set of tables similar to Kulik's† for the catenary, the labor of computation becomes so great as to be almost prohibitory. In the mean time I have therefore contented myself by suitably stretching a chain across the chart of observed results (electromotive force in terms of temperature) for iridio-platinum, and noting the essential similarity of the two curves in question.

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ART. XLI.—*Gases in Kilauea;* by WILLIAM LIBBEY, JR., Professor of Physical Geography, Princeton, N. J.

IN 1865 Mr. W. T. Brigham called attention to the existence of certain bluish-green flames which broke from the crust of Halemaumau during a disturbance of its slag-like surface.

In 1887 Mr. Emerson of the Geological Survey of the Islands and several others identified these same flames. They are referred to in Prof. Dana's book upon "The characteristics of Volcanoes" (p. 119) as being pale in color and of a slightly greenish color rather than bluish. This corresponds with my own observations. In order to test this matter I took with me upon my recent visit to the volcano (Sept. 14th to 25th, 1893) a pocket spectroscope. I did not imagine that I should have such a splendid opportunity or I should have taken a better instrument; however the little spectroscope did good service and the observations may possibly lead to something better later on.

I spent the greater part of three evenings down on the edge of the boiling cauldron in Halemaumau and the observations I made were repeated many times so that I have every confidence in them. As to the conditions I may say that they were exceptionally favorable. The surface of the molten lava was so high during the whole of our visit that it could be reached with an ordinary walking stick. The volcano seemed to be in a very active state as several overflows occurred, and the ebullition from what appeared to be three centers of weakness or disturbance were very remarkable. The lava was thrown into the air for a distance of 40 to 50 feet and as we could approach

* Barus: Phil. Mag., xxxiv, p. 376, 1892.
† Kulik: Theorie und Tafeln der Kettenlinie, Prag, 1832.

these fountains quite closely in two instances, we could form very good estimates of their size and the amount of lava involved in such an outbreak. The surface for a considerable area near one of these centers (for they seemed very constant in position) would sway up and down, at first gently and then more violently, particularly in the neighborhood of the intersection of the fissures which were constantly forming in the crust of slag, then there would be two or three small explosions accompanied by a bumping sound, as though gas had escaped from the mouth of an uncorked bottle; after this there would be a great rush of lava into the air, to be repeated several times; when the surface would become quiet once more.

At the edge of this cauldron, 1000 feet in diameter, I placed myself after dark and for a couple of hours in each instance had opportunities nearly every five minutes to observe the flames which almost invariably accompanied these explosions. At times they would make their appearance along the fissures, in the crust when they would be very short lived; and I failed to get much information concerning them, aside from the fact that they seemed the exact counterpart of the hydrogen flame from a Bunsen burner.

It was the study of the flames which accompanied the larger outbreaks which appeared to promise most return. Getting as near as possible to one of the giant fountains (probably 50 yards distant) I watched for the premonitory symptoms of an outbreak and got all ready for it, and seldom failed to catch indications of the presence of gases.

For a good part of the time there was a continuous spectrum while the spectroscope was directed across the lava. The first thing that impressed me was the sudden appearance and disappearance of broad *bands* of bright light, showing conclusively the presence of gas burning under high pressure. The location of these bands became the next problem and then I longed for a better instrument with a micrometer eyepiece. The first which appeared with constancy was a band in the green, indicating the presence of carbonic oxide in all probability. Then I found on other occasions bands of lighter intensity in the red and blue, and the red and purple portions of the spectrum, thus apparently marking the presence of the hydro-carbons. There were also occasionally noticed upon a full spectrum a large series of dark lines in the yellow and orange, sometimes completely blotting these colors out of the spectrum altogether. These need more careful study before assigning them definitely to any substance or substances.

It is hoped that the above may serve to indicate a point upon which valuable work can be done and that some one will take advantage of it and follow the subject up.

ART. XLII.—*A Simple Method of Determining the Eccentricity of a Graduated Circle with one Vernier;* by F. L. O. WADSWORTH.

IN certain forms of instruments intended for angular measurements only one vernier is provided, either because the graduated arc is less than 360°, as in the case of the sextant, position circle and other instruments of that class, or because, as in certain forms of spectrometers, in which the vernier is attached to the arm which carries the view telescope, it is of advantage, from the point of view of mechanical simplicity or convenience, to use but one. Except for the trouble involved in determining and applying the necessary corrections to the reading there is no serious objection to the use of a single vernier, for if the mechanical work is reasonably well done little change may be expected in the instrument even after very considerable use.

In this case however it becomes necessary to determine accurately the errors of graduation—particularly those due to eccentricity, and the method usually resorted to, is to remeasure with the instrument whose circle it is desired to test, a series of angles whose value has been first carefully determined with another instrument whose constants are all known. This method involves a very considerable amount of work even if rendered possible by the possession of a suitable instrument.

Recently the writer had occasion to test the error of eccentricity of the graduated circle of a spectrometer, of the class alluded to above, and as no other instrument was just then available for checking its angular readings, the following simple method was devised for this purpose.

A piece of plane parallel glass (an ordinary sextant mirror) is silvered on the face, *a*, fig. 1, and mounted on the prism

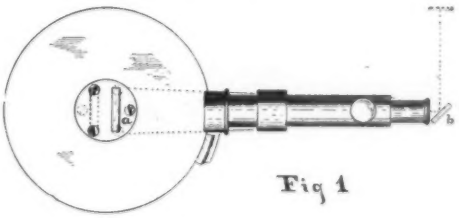


Fig 1

stand, or on a bit of board provided with three leveling screws, as shown, with a little soft wax or cement. The whole is then placed on the spectrometer table and the mirror face set

perpendicular to the plane of the circle in any convenient way, say by adjusting it until the image of any distant object as seen by reflection from the silvered surface occupies the same position in the field of the observing telescope when the mirror is either in the position shown, or is turned through 180° as shown by the dotted lines.

The telescope is then set with its axis perpendicular to the mirror by making the image of the cross wires coincide with the wires themselves, the wires being illuminated for this purpose by placing a small piece of unsilvered glass, b, in front of the eyepiece at an angle of about 45° so as to throw the light from a gas flame or window into the field of the telescope. There is no difficulty in seeing the image by placing the eye behind and close to b.*

The single vernier attached to the telescope is then read, and either the circle, carrying with it the mirror, or the telescope is turned through 180° or until the image of the vertical cross wire as seen by reflection from the other side of the silver coat (this time through the glass), is again in exact coincidence with the wire itself and a second reading of the vernier taken. If the unsilvered face of the mirror is parallel to the silvered face the angle through which the telescope or circle is turned between these two settings will be just 180°, if they are not parallel it will be $180 \pm \frac{1}{2}\varphi$, where $\frac{1}{2}\varphi$ is the deviation due to the prismatic form; equal approximately to $\frac{1}{2}$ the angle φ between the faces .... Usually however the error of parallelism in a good sextant glass is not more than 5″ and the resulting error in angle consequently only 2″ to 3″, a quantity smaller than the venier will ordinarily indicate. If larger however the effect may be readily eliminated by reversing the glass on the spectrometer table, repeating the settings and taking the mean of the readings. Then if ε be the eccentricity of the circle and θ the angle between the 0 of graduation and the line of centers of rotation and graduation, α the circle reading for the first setting, β that for the second setting . . . then evidently

$$m = \text{true angular reading for 1st setting} = \alpha + \varepsilon \sin(\alpha+\theta)$$
$$n = \text{“ “ “ “ 2d “ “} = \beta + \varepsilon \sin(180+\alpha+\theta)$$
$$m-n = 180^\circ = \alpha-\beta+2\varepsilon \sin(\alpha+\theta)$$
$$\Delta_1 = 180^\circ-(\alpha-\beta) = 2\varepsilon \sin(\alpha+\theta) \qquad (1)$$

If now we take a second set in which the first reading is γ and the second δ we have

* The setting of the mirror perpendicular to the plane of the circle and of the telescope at right angles to the mirror is readily accomplishad at one and the same operation, for the telescope can first be set perpendicular to the mirror face, the latter then turned through 180° and the vertical difference between image and cross wires, corrected, half by adjustment of the mirror, half by the adjustment of the telescope.

$$\Delta_2 = 180-(\gamma-\delta) = 2\varepsilon \sin(\gamma+\theta) \qquad (2)$$

If the second set is made with the faces of the glass at right angles to the position they occupied in the first set and if farther the first setting is made when the circle reads 0; we have simply

$$\text{tang } \theta = \frac{\Delta}{\Delta_2} \qquad (3)$$

$$\varepsilon = \tfrac{1}{2}\sqrt{\Delta_1^2+\Delta_2^2} \qquad (4)$$

In case the graduated arc is less than 180° the eccentricity can still be determined by the same method by the use of two mirrors mounted together on a single block as shown in fig. 2.

The first mirror a is as before a sextant glass silvered on one side and the second mirror b is placed behind it and inclined to it at a small angle, sufficient to allow the surface of a to be seen normally by reflection from b as shown by the dotted lines. The mirror a is first set perpendicular to the plane of the divided circle and the observing telescope perpendicular to it as before. The second mirror is then brought to perpendicularity to the axis of the telescope and to the divided circle. The telescope is set to perpendicularity with the first surface, and the reading of the circle taken, then to perpendicularity with the opposite side of the same surface as seen by reflection from b and a second reading taken.

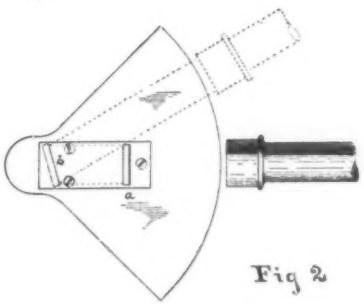


Fig 2

Using the same notation as before,

$$m = \alpha+\varepsilon \sin(\alpha+\theta)$$
$$n = \beta+\varepsilon \sin(\beta+\theta)$$

Let ω denote the angle between the two glasses;

Then $m-n = 2\omega^* = \alpha-\beta+\varepsilon \sin(\alpha+\theta)-\sin(\alpha+2\omega+\theta)$

$$2\omega-\Delta'_1 = \varepsilon \sin(\alpha+\theta)-\sin(\alpha+2\omega+\theta) \qquad (5)$$

A second and third set of readings taken at different points on the same circle gives the two additional equations necessary for the determination of the three unknown quantities ω, ε, and θ.

*If the glass a is wedge-shaped the angle $m-n$ will not be exactly 2ω, but $2(\omega \pm \frac{1}{2}\phi)$. The effect however is the same as if the angle ω had been changed to $\omega' = \omega \pm \frac{1}{2}\phi$.

$$2\omega - \Delta'_2 = \varepsilon \sin(\gamma+\theta) - \varepsilon \sin(\gamma+2\omega+\theta) \quad (6)$$
$$2\omega - \Delta'_3 = \varepsilon \sin(\psi+\theta) - \varepsilon \sin(\psi+2\omega+\theta) \quad (7)$$

If the settings are taken by repetition so that $\gamma = \alpha+2\omega$ and $\psi = \gamma+2\omega = \alpha+4\omega$, and the first setting is made when the circle reads 0, we have

$$2\omega - \Delta'_1 = \varepsilon \sin\theta - \varepsilon \sin(\theta+2\omega)$$
$$2\omega - \Delta'_2 = \varepsilon \sin(0+2\omega) - \varepsilon \sin(\theta+4\omega)$$
$$2\omega - \Delta'_3 = \varepsilon \sin(\theta+4\omega) - \varepsilon \sin(\theta+6\omega)$$

If many arcs are to be tested it would be convenient to have a prism cut to a convenient angle of either of the forms shown in fig. 3.

Fig 3

In the first of these forms, the faces a, b, c are polished and a and b are silvered.

In the second form, only the two adjacent faces a, b are polished and silvered.

The angle 2ω may be determined carefully once for all, and the number of sets of readings necessary for the determination of the eccentricity reduced to two, as only the two unknown quantities ε and θ then remain to be determined.

It is obvious also that in the determination of the eccentricity of a complete circle we may use an ordinary 60° prism instead of the plane parallel glass silvered on one side—the only disadvantage being that the reduction of the observations is not quite so readily accomplished.

If we know the angle of the prism $(60° \pm \delta)$, two sets of readings only are necessary, and we have

$$\Delta'_1 - 2\omega = \Delta_1 = \tfrac{3}{2}\varepsilon \sin\theta - \frac{\sqrt{3}}{2}\varepsilon \cos\theta$$

and for a second set 90° from the first,

$$\Delta_2 = \tfrac{3}{2}\varepsilon \cos\theta + \frac{\sqrt{3}}{2}\varepsilon \sin\theta$$

whence
$$\text{tang } \theta = \frac{\sqrt{3}\,\Delta_2 + 3\Delta_1}{3\Delta_2 - \sqrt{3}\,\Delta_1}$$

and
$$\varepsilon = \frac{\sqrt{\Delta_1^2 + \Delta_2^2}}{\sqrt{6}}$$

If the angle of the prism is not known three sets are necessary and the resulting equations are the same as those already deduced—(5), (6), (7)—from which the values of the three unknown quantities ω, ε, and θ may be calculated as before.

Astro-Physical Observatory, Smithsonian Institution,
Washington, D. C., January, 1894.

ART. XLIII.—*Transformations of Mechanical into Chemical Energy. Third Paper. Action of Shearing Stress continued;* by M. CAREY LEA.

THAT mechanical energy may be transformed into chemical, has been, I believe I may say, well proved by the reactions described in the previous papers of this series. But the matter is one of sufficient importance to make it desirable to accumulate evidence and to obtain a solid foundation of fact on which to rest the argument.

In the paper which described the effects of shearing stress (this Journal, Dec. 1893), I was able to cite one instance only in which the decomposition product was obtained in easily weighable quantities. More lately others have been obtained, among them one, mercuric oxide, in which it can be determined how many units (gram-meters) of mechanical energy have been transformed into chemical.

Silver-oxide precipitated and dried in the absence of daylight is soluble without residue in ammonia. After trituration therefore, the unchanged portion is easily removed by that solvent.

1. Half a gram of silver-oxide wholly soluble in ammonia was triturated for 20 minutes in a porcelain mortar the unchanged portion was removed by ammonia, the residue was treated with nitric acid, filtered, and the silver thrown down by hydrochloric.

Silver chloride obtained	·0402
Corresponding to metallic silver	·0303

The use of a porcelain mortar is attended with the disadvantage that during the prolonged and forcible grinding necessary, a very appreciable amount of material is removed from the mortar and pestle, which must be separated from the product subsequently. I have therefore made some comparative experiments with a large agate mortar and an agate pestle provided with a stout wooden handle adapted for the use of as much force as with a porcelain mortar. But even under the most favorable conditions, the efficiency of such a mortar is (as will be seen) only one-fifth to one-tenth that of a porcelain mortar of the same size. This is largely due I think, to the high polish which is very unnecessarily given to the inside of agate mortars.

It is therefore better to make use of a porcelain mortar, taking adequate means afterwards to separate the material abraded.

2. The same quantity of silver oxide was triturated also for 20 minutes, in an agate mortar. As the abrasion is inappreciable it was only necessary to dissolve out the unchanged oxide with ammonia. There was left

Metallic silver	·0048

showing the much less efficiency of the agate mortar.

Mercuric Oxide.—The specimen taken was examined for its solubility in cold dilute (one-tenth) hydrochloric acid, in which it dissolved slowly but completely.

Half a gram was taken and after trituration the unchanged oxide was dissolved out by repeated digestions with hydrochloric acid. There remained mercurous chloride, a trace of metallic mercury, and as a porcelain mortar was used, abraded porcelain. The reduction products were dissolved out by a few drops of aqua regia, were filtered and precipitated by hydrogen sulphide.

Mercuric sulphide obtained	·0354
Corresponding to Hg	·0305
And to mercuric oxide	·0329

This therefore (disregarding the traces of metallic mercury), is the amount of mercuric oxide which underwent reduction to mercurous oxide.

The oxidation of mercury to mercurous oxide and that of mercurous to mercuric are both exothermic reactions. As respects the thermic equivalent of the oxidation of mercury to both its oxides, quite different numbers have been found by different chemists. Nevertheless if from these different numbers we calculate the amount of heat disengaged by the combination of Hg_2O with O we get almost exactly the same figures whether we use Thomsen's results as modified by Nernst, or those of the French chemists; it matters little therefore which are taken. Ditte in his work "Les Métaux" (Fascicule II, p. 500) adopts the numbers 21·1 and 15·5 respectively.

On this basis, the amount of energy that must be supplied to convert 2HgO to Hg_2O+O (endothermic) is that which corresponds to 9·9 great calories. Therefore 400 grams of mercury existing in the state of mercuric oxide will require that amount of energy supplied to reduce it to mercurous oxide. One gram therefore will require the equivalent of 24·75 small calories and one milligram, ·02475.

In the experiment described mercurous oxide corresponding to 30·5 mgs. metallic mercury was obtained. The energy required to reduce 30·5 mgs. existing as mercuric oxide to mercurous corresponds to 0·755 water gram degrees and this again to 321·5874 gram meters. This number therefore, 322

gram meters, represents the amount of mechanical energy transformed into chemical energy in the above operation.

Potassium Ferricyanide.—A good method of obtaining this salt absolutely free from ferrocyanide is to dissolve the commercial product in hot water and add a little potassium permanganate by degrees until the solution takes a faint reddish color. Very little is usually required. The solution is then filtered and crystallized, taking the first crystals only.

Ferricyanide purified in this way, was triturated about 20 minutes in an agate mortar. On adding water a deep green solution was obtained which by standing and warming let fall abundance of a blue powder.

Ferric Ammonia Alum.—A specimen of this salt which, when tested with potassium ferricyanide gave a pale wine colored solution without a trace of green, was taken and 3 decigrams were triturated for 25 minutes in a porcelain mortar.

After trituration the ferrous salt formed distinctly reduced gold solution. A few drops of the dissolved substance being added to a solution of ferricyanide changed it to an intense green color. Undoubtedly reduction had taken place. It need scarcely be mentioned that in this case the tests should be applied immediately after the trituration. A few hours interval completely changes the reactions owing to the re-oxidation of the ferrous salt formed.

This experiment was repeated with additional precautions. To a strong solution of ferric ammonia alum, enough potash permanganate was added to distinctly color the liquid which was then made to crystallize quickly by cold. These crystals, certainly free from ferrous salt, were then actively triturated in a porcelain mortar for 25 minutes. The filtered solution produced immediate purple clouds in a cold very dilute solution of gold chloride and an abundant blue precipitate in one of potassium ferricyanide.

It is essential that the ferric alum be thoroughly dried (at a temperature not exceeding 40° C.), otherwise owing to the large quantity of water of crystallization it will become pasty in grinding and then no reduction will take place.

Cupric Chloride.—Even by long trituration this salt showed no indication of reduction.

This reaction taken with the preceding shows how distinct is the action of mechanical energy from that of heat. For cupric chloride is reduced by heat to cuprous chloride, but shearing stress has no such action. On the other hand shearing stress reduces ferric sulphate which heat does not.

Sodium Chloraurate.—In the previous paper, the effect of triturating this salt in a porcelain mortar was given. For comparison it has since been tried in an agate mortar. With

20–25 minutes' trituration, 3 decigrams gave 2·7 milligrams metallic gold, showing as in other cases the much lower efficiency of the agate mortar.

Silver Carbonate.—Half a gram was triturated about 25 minutes in a porcelain mortar. It darkened much. The unaltered carbonate was dissolved out by exhausting repeatedly with ammonia. The residue was treated with nitric acid, filtered and the silver thrown down by hydrochloric acid. It amounted to 11 milligrams corresponding to

Metallic silver	·0083

Silver Sulphite was precipitated in a dark room by alkaline sulphite and treated in the same manner as the foregoing. Silver chloride obtained ·0092 corresponding to

Metallic silver	·0069

Silver compounds although easily giving weighable results, are not well suited for determining the transformation of energy that takes place. It is probable that the reduction is to argentous salt, but it is not certain. Ammonia decomposes argentous salts into argentic salts that dissolve and metallic silver that remains. So that whether we consider the reduction as being to argentous salt or to metal, in either case we find the same quantity of metallic residue after treatment with ammonia and cannot distinguish with certainty.

It scarcely needs to be said that the object of these various determinations is not to establish any relation between the quantity of substance taken and the amount of decomposition that ensues, for none exists. It often happens that when a larger quantity is taken there results a diminished decomposition product, the particles protect one another. And even when all other things are equal the product will depend on the activity and dexterity with which the grinding is done.

But what is really important is that the amounts obtained enable us in particular cases, to determine the exact amount of mechanical energy which has been transformed.

In concluding this paper, two cases will be mentioned which do not belong to the above category, inasmuch as the reductions are exothermic. As a general rule, to cause substances to part with oxygen, energy must be supplied, but there are exceptions. Auric oxide, for example, disengages heat in parting with oxygen and the same is the case with potassium permanganate.

Auric Oxide.—As just said the reduction of auric oxide is exothermic. Thomsen found the equation for its formation

$$2Au + 3O + 3H_2O = 2Au(OH)_3 - 2 \times 6{\cdot}6C$$

The production therefore of a molecule of auric hydroxide requires that 6·6C be supplied. We should therefore expect to find gold hydroxide more easily and more largely reduced by shearing stress than other oxides.

Experiment confirms this expectation and although this case does not belong to the subject proper of this paper which deals with endothermic reactions, it seems sufficiently interesting to add in this appendix.

Gold trioxide hydrate $Au(OH)_3$ was obtained by Figuier's method (a gold solution is rendered strongly alkaline with potash or soda and barium chloride is added as long as it causes a precipitate. Part of the gold remains in solution. The barium aurate is washed and decomposed with very dilute nitric acid). The brown powder after drying was ascertained to be completely soluble in warm dilute hydrochloric acid (1 to 10) showing that no gold had been reduced.

(1) Of gold oxide ·155 gms. were taken and were triturated 25 minutes in a porcelain mortar. The large reduction was at once evident to the eye, the pestle looked as if plated with bright gold. The unchanged portion of oxide was removed by digesting with dilute hydrochloric acid. The metallic gold was dissolved in aqua regia, filtered, reduced and weighed.

It amounted to ..... ·0718

The 155 mgs. of gold oxide taken contained 123·1 of gold. The reduction was therefore as 718 to 1231. Fifty-eight per cent or more than half the gold contained in the material employed was reduced.

(2) 200 mgs. gold oxide were triturated 30 minutes in a porcelain mortar. After removing the unchanged oxide as above the metallic gold was dissolved, filtered and reduced—

Obtained ..... ·0538

Potassium Permanganate.—Two molecules of permanganate by reduction to $2MnO_2H_2O$ lose 3 atoms of oxygen and at the same time 28·4 Cal. The reaction is therefore exothermic.

By active trituration a portion of the permanganate taken easily undergoes reduction. Exhausted with water, a brownish black insoluble residue remains which dissolves with effervescence in strong warm sulphuric acid forming a violet solution—the residue is therefore manganic peroxide.

Three estimations were made. A first rough one, after trituration for 25 minutes in a porcelain mortar, gave of washed and dried material which had become insoluble, 43 mgs.

The second was made on a like quantity of permanganate also in a porcelain mortar. The portion rendered insoluble was dissolved in hydrochloric acid and estimated as Mn_3O_4.

Quantity obtained	·0136

showing that 28·25 mgs. of permanganate had been reduced to MnO_2.

The same quantity of permanganate treated in the same way in an agate mortar gave only ·0030 MnO_2 owing to the less efficiency of the mortar.

The reductions in the case of these last two substances are exothermic, they however do not take place spontaneously, but require the aid of an exterior force—this aid is supplied by shearing stress.

In these three papers a large number of reactions have been described in which mechanical energy has been transformed into chemism. The number might be extended, but in practice is necessarily limited to those cases in which a perfect separation can be made between the original substances and the altered product.

ART. XLIV.—*The Detection and Separation of Arsenic associated with Antimony and Tin;* by F. A. GOOCH and B. HODGE.

[Contributions from the Kent Chemical Laboratory of Yale College—XXIX.]

UPON the well known fact that hot strong hydrochloric acid is capable of dissolving the sulphides of antimony and tin while exerting solvent action to a very slight degree upon arsenious sulphide is based the simplest and most rapid method in common use for the separation of arsenic from antimony and tin. Unfortunately, however, the forcible treatment necessary to bring about the solution of large amounts of antimony is sufficient* to dissolve small quantities of arsenious sulphide, so that for the purposes of general analysis the method is inadequate. Koehler† has shown that only the arsenic is precipitated, and that very completely, when hydrogen sulphide acts upon the solution of arsenious and antimonious salts in hydrochloric acid of 20 per cent strength, but

* Rose-Finkener. Anal. Chem., ii, 423.
† Zeit. für Anal. Chem, xxix, 192.

the adaptability of Koehler's treatment to the detection of arsenic in the ordinary course of analysis is limited by the necessity of so constituting the solution to be tested that hydrogen sulphide shall occasion no deposit of free sulphur to conceal or be mistaken for a precipitation of arsenious sulphide. In the course of analysis the mixed sulphides of arsenic, antimony, and tin, remaining after the removal of the sulphides insoluble in alkaline sulphides and recovered from solution by the action of hydrochloric acid, require for their complete solution the action of an oxidizing agent which must, of course, interfere with the immediate use of Koehler's method. If simple means can be found for the destruction of the excess of the oxidizing agent and the simultaneous reduction of the arsenic and antimony to the lower condition of oxidation, it is plain that the test for arsenic by passing hydrogen sulphide into the solution of antimony and tin in hot hydrochloric acid of half-strength should be sure and easy. In a former paper from this laboratory* a method was described for the quantitative separation of arsenic from antimony, based upon the reduction and volatilization of salts of arsenic by the action of a current of gaseous hydrochloric acid upon the solution containing potassium iodide. It is this reaction—the reduction of arsenic and antimony and the volatilization of the former by the simultaneous action of potassium iodide and hydrochloric acid—which we have now endeavored to apply in simple form to the rapid detection of small amounts of arsenic associated with antimony and tin. We have studied the effect of repeated distillations of small portions of concentrated hydrochloric acid upon mixtures of the salts with potassium iodide. The apparatus which we employ is essentially the distillation apparatus of Mohr, and consists of a 25cm³ flask fitted by means of a rubber stopper to a pipette bent, drawn out at the lower end, and dipped into a test tube which is at the same time supported and cooled in a flask partly filled with water. The pipette tube is wide enough (about 0·7cm in diameter) to prevent the formation of bubbles within it, and the bulb, holding about 20cm³, is sufficiently large to retain any liquid which may be momentarily forced back by the accidental cooling of the flask during the distillation.

In the test experiments recorded below the arsenic was introduced into the flask in the form of arsenic acid dissolved with 3 grm. of potassium iodide in 5cm³ of water, an equal volume of the strongest hydrochloric acid (sp. gr. 1·20) was added, the distillation was carried nearly to dryness, and the distillate was

* Gooch and Danner, this Journal, xlii, 308.

condensed in 10cm³ of a mixture of strong hydrochloric acid and water in equal parts. The iodine evolved during the distillation was bleached by the addition to the distillate of stannous chloride dissolved in hydrochloric acid of half-strength, and hydrogen sulphide was passed to precipitate the arsenic if present. The residue in the flask was treated with 10cm³ of the strongest hydrochloric acid and the process of distillation was repeated, but this time the distillate was condensed in 10cm³ of water in order that the final acidity of the liquid should be that of acid of half-strength, and so, after bleaching by stannous chloride, immediately available for the test for arsenic by hydrogen sulphide. Subsequent treatments of the residue were carried out similarly until arsenic ceased to appear in the distillate.

The results of experiments (1) to (5) show that four successive distillations of 10cm³ portions of the strongest acid are enough to transfer 0·01 grm. of arsenic completely to the distillate, while a single distillation appears to be sufficient to volatilize anything less than 0·003 grm.

Experiments (6) to (9) made similarly with antimony, taken in the form of purified tartar emetic and oxidized by iodine in alkaline solution previous to treatment, either alone or with arsenic, show that antimony is discoverable in the residues when even so little as 0·0001 grm. of that element is originally introduced, though it was very evident that a portion of the antimony may pass to the distillate when much of it is present in the flask. Indeed when large quantities of antimony are treated the appearance of the brownish-red fumes of antimonious iodide in the distilling tube may serve as a very good indication that the concentration should go no further, since the antimonious iodide may, if it reaches the receiver in quantity, impart to the distillate a color which is not discharged, by the stannous chloride used to bleach the iodine and which makes it necessary to look subsequently for a precipitate of arsenious sulphide in a liquid of its own tint. The amount of antimony volatilized seems to be proportioned to the amount present, and, if the distillation is properly conducted, enough antimony remains in the residue to be found if it was originally present in discoverable quantity.

The results of similar work with tin alone, and with tin and arsenic, are recorded in experiments (10) to (15), and the evidence goes to show that, though like antimony it may pass to the distillate under the conditions, enough tin always remains to be found in the residue, if the amount originally taken was discoverable.

	Arsenic taken as H_3O_3AsO. grm.	Antimony taken as H_3O_3SbO. grm.	Tin taken as $SnCl_4$. grm.	Precipitation by H_2S in successive distillates.	Precipitation by H_2S in the residue dissolved in water.
(1)	0·0001	----	----	I. Found. II. None.	None.
(2)	0·0033	----	----	I. Found. II. None.	None.
(3)	0·0050	----	----	I.–III. Found. IV. None.	None.
(4)	0·0100	----	----	I–IV. Found. V. None.	None.
(5)	0·1000	----	----	I–VII. Found. VIII. None.	None.
(6)	----	0·0001	----	I. None.	Distinct color.
(7)	0·0050	0·0001	----	I–IV. Found. V. None.	Distinct color.
(8)	0·0001	0·4	----	I. Found. II. None.	Large.
(9)	0·0100	0·4	----	I–IV. Found. V. None.	Large.
(10)	----	----	0·0001	I. None.	Distinct color.
(11)	0·0100	----	0·0001	I–IV. Found. V. None.	Distinct color.
(12)	0·0001	----	0·0005	I. Found. II. None.	Distinct.
(13)	0·0100	----	0·0005	I–IV. Found. V. None.	Distinct.
(14)	0·0001	----	0·5	I. Found. II. None.	Large.
(15)	0·0100	----	0·5	I–IV. Found. V. None.	Large.

It is plain that a single distillation, which may easily be completed in five minutes, is sufficient to discover the presence of 0·0001 grm. of arsenic associated with so much as 0·4 grm. or 0·5 grm. of antimony or tin.

It is also evident that amounts of arsenic not exceeding 0·003 grm. may be completely removed from the residue by a single distillation. When larger amounts of arsenic are to be removed, so that the tin and antimony may be obtained free from that element, the result may be accomplished by repeating the distillation sufficiently; or, inasmuch as only a little iodine remains after the first distillation, the end may be attained by dissolving the residue in hydrochloric acid of half-strength, bleaching the iodine with exactly the necessary amount of sulphurous acid or sodium thiosulphate (since the use of the stannous chloride is here precluded), and passing hydrogen sulphide.

ART. XLV. — *On the Presence of Water in Topaz;* by PAUL JANNASCH and JAMES LOCKE.

WE give in the following article the first results of an investigation of the mineral topaz, which we have undertaken in connection with our recently published work on the formula of the axinite from Bourg d'Oisans.* As the first step in this investigation we subjected the mineral to a careful examination for water, and have found, as the analyses below show, that it contains a very significant quantity of water of constitution.

The method which we employed to detect and estimate the water has been described by us in detail in another article,† but it may be well to explain again its principle and some of the precautions which we took to secure accurate results. The substance was mixed with lead oxide in a bulb-tube and strongly fused over the flame of a Bunsen burner, and the escaping water received in a weighed calcium chloride tube. To retain any traces of hydrofluoric acid or silicon fluoride which might also be evolved, a layer of lead oxide about an inch long was placed in the posterior arm of the bulb-tube. The lead oxide used was in some cases the purest article to be obtained from Merck, in others we prepared it ourselves by precipitating lead acetate with ammonium carbonate, thoroughly washing by decantation, evaporating to dryness and igniting the residue in a platinum dish. The ignited product was placed, while still warm, over potassium oxide under a bell-jar and kept there when not in use. After being introduced into the tube, but before its mixture with the powdered mineral, each portion of lead oxide was freed from the last traces of moisture by gentle ignition in a current of dry air. We watched carefully, in every one of the experiments, for signs of escaping hydrofluoric acid or silicon fluoride, but could detect neither: the glass remained perfectly smooth and unattacked throughout, and the water, which could be plainly seen as it condensed in the cold part of the bulb-tube and in the bulb of the calcium chloride tube, showed no trace of silica.

The specimens of topaz examined were in every case fresh and well formed crystals, and absolutely free from foreign substances. The analyses cover four varieties, one of which contained nearly 3·0 per cent of water, the others approximately 1·0 per cent. The analytical results follow:

* Zeitschrift für Anorgan. Chemie, Bd. vi, Heft 1.
† Ibid., Bd. vi, Heft 2.

Locality and Description.	Substance taken.	Water found.	Per cent.	Average.
I.				
San Luis, Mexico.	0·5128 gr.	0·0040 gr.	0·79	
Small crystals; 1,	0·5234	0·0046	0·88	= 0·81%
2, white; 3, brown.	0·4890	0·0036	0·74	
II.				
Ilmen Mts. Large	0·5422	0·0057	1·05	
white crystals.	0·5554	0·0055	0·99	= 1·02%
III.				
Schneckenstein Saxony. Small gray-	0·5743	0·0073	1·27	
white crystals.	0·5564	0·0071	1·28	= 1·28%
IV.				
Brazil. Large	0·4954	0·0140	2·82	
brown crystal.	0·6308	0·0164	2·60	= 2·69%
	0·5263	0·0140	2·66	

To assure ourselves that the presence of the water was not due to organic substances or other impurities in the lead oxide we made two additional determinations; one, of the water given off by the lead oxide alone, the other conditions of the experiment being observed; the second, of the water in the specimen from the Ilmen Mountains by means of lead oxide which had been previously fused. In the first determination the calcium chloride tube increased in weight by an amount corresponding to less than 0·1 per cent of the quantity of mineral usually taken for analysis, and the second experiment yielded results agreeing with those previously obtained.

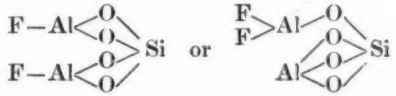
Whether the presence of water will necessitate any radical change in the formula of topaz we are not yet in position to state. We are at present engaged, however, in making several complete analyses of different varieties of the mineral, and hope soon to be able to decide this question.

Heidelberg, Feb. 17, 1894.

ART. XLVI.—*On the Chemical Composition and Related Physical Properties of Topaz;* by S. L. PENFIELD and J. C. MINOR, Jr.

THE chemical composition of topaz has never been satisfactorily settled. The results of the analyses thus far published show clearly that silicon and aluminium are present in the proportion of 1 : 2, but the percentage of fluorine as given in them varies from 16·12–18·83. The formula that is usually

accepted is that of Groth* $[Al(O.F_2)]\ AlSiO_4$, corresponding to an isomorphous mixture of $(AlF_2)\ AlSiO_4$ with the andalusite molecule $(AlO)\ AlSiO_4$ in which the former predominates and in which fluorine is supposed to be replaced by oxygen. Rammelsberg† suggests a mixture of Al_2SiO_5 and Al_2SiF_{10} in the proportion of 5 : 1. The ratio of $SiO_2 : Al_2O_3 : F$ varies from 1 : 1 : 1·50 to 1 : 1 : 1·84 and if this could be shown to be 1 : 1 : 2 the composition could be expressed by either of the following simple orthosilicate formulæ:



Since it has been shown by one of us that hydroxyl so frequently replaces fluorine, and it now seems very doubtful if bivalent oxygen ever plays this rôle, the idea has suggested itself that perhaps the variations in the percentages of fluorine and the failure to yield a simple ratio are due to the partial replacement of fluorine by hydroxyl. Accordingly tests were made for water and it has been found to be always present. This fact seems to have been generally overlooked.‡

In testing by the ordinary closed tube method it is not always evident that hydroxyl is present, since in a mineral like topaz an acid vapor comes off, probably hydrofluosilicic acid, instead of water. By mixing the mineral, however, with lime or some other substance to hold the fluorine, water is evolved. In order to determine to what extent hydroxyl is present and what part it plays in the chemical composition, material from a number of localities has been examined, and it will be shown in the course of this article that the variations which topaz shows both in chemical composition and physical properties result from an isomorphous replacement of fluorine by hydroxyl, while a simple composition has been established which can be expressed by the formula $[Al(F.OH)]_2SiO_4$.

Method of analysis.—The important features of the analysis were of course the accurate determination of fluorine and water. For fluorine the method of Berzelius was adopted. The mineral, mixed with half its weight of quartz, was fused with five times the total weight of mixed sodium and potas-

* Tabellarische Uebersicht der Mineralien, 1889, p. 106.

† Mineralchemie, 1875, p. 580.

‡ As this article was going to press, we have observed in Nos. 2 and 3, vol. vi of the Zeitschrift für anorganische Chemie, p. 168, March, 1894, which has just come to hand, that Jannasch and Locke have also determined the presence of water in topaz with the following results, but they have not discussed the relation of the water to the chemical composition.

San Luis, Mexico.	Ilmen Mountains.	Schneckenstein.	Brazil.
0·80	1·02	1·28	2·69

sium carbonates. The fusion was soaked out, filtered and washed with hot water. To the hot filtrate five to ten grams of ammonium carbonate were added and after cooling, still another addition of the same reagent. After standing in the cold for twelve hours the precipitate was filtered off, the excess of ammonium carbonate expelled from the filtrate by heating in a platinum dish on the water bath, and an ammoniacal solution of zinc oxide added. After evaporating until the odor of ammonia had disappeared the zinc oxide precipitate was removed by filtration, the filtrate heated and dilute nitric acid added until the excess of alkali carbonate was nearly decomposed. To the slightly alkaline, boiling solution an excess of calcium chloride was added and from this point the precipitate was treated as previously described by one of us.* That determinations made by this method are satisfactory was proved by the following: In an experiment with topaz the residue resulting from soaking out the alkali carbonate fusion, and the precipitates formed by the ammonium carbonate and zinc oxide were united, mixed with a fresh portion of alkali carbonates, fused and treated as before. The amount of fluorine that was obtained by this second treatment was only 0·07 per cent, showing that practically all can be extracted by one fusion. Moreover, fluorine determinations were made by the above method in an artificial mixture of cryolite, cyanite and quartz, taken in proportions to correspond with the composition of topaz with the following results.

Cryolite taken.	Fluorine calculated.	Fluorine found.	Loss.
·3325	·1805	·1788	·0017

This result indicates only a slight deficiency, and it is probable that the determinations in the regular topaz analyses are not over 0·20 per cent low, as usually a gram and sometimes a gram and a half of the mineral are taken for a determination. In the above no allowance has been made for what might be recovered by a second fusion of the residues, and probably some of the loss is occasioned by volatilization during the alkali carbonate fusion, but since the crucible was kept covered this must have been very slight. Since water is present, it is evident that attempts that have been made to determine fluorine by loss on ignition, assuming that silicon fluoride is given off, can not have given reliable results. For the determination of water, the mineral has been fused with dry sodium carbonate and the water absorbed in a weighed sulphuric acid tube. The method, which has been carefully tested, gives accurate results. The mineral is completely decomposed and it is impossible for acid

* This Journal, III, xlvii, p. 190, 1894.

vapors to pass off with the water.* There can be no doubt about the water having come from hydroxyl, since it is not driven off except at an intense heat. In an experiment on topaz from Stoneham, Me., where the water was found to be 0·98 per cent, the powder suffered a loss of only 0·12 per cent by heating for a long time in a platinum crucible at the highest heat of a ring burner.

The remainder of the analysis was conducted in the ordinary manner.

Material for analysis.—The specimens which we have examined are from the following localities:

Stoneham, Maine.—The material was colorless and transparent and was taken from the center of a large crystal in the Brush collection, catalogue number 185. Analyses have also been made by Genth† and Whitfield.‡ The former found 18·83 and the latter 17·10 per cent of fluorine, also Na_2O 1·25, K_2O 0·14 and H_2O 0·20 per cent. A careful test that we have made for alkalies has shown that they are absent.

Pike's Peak, Colorado.—A perfectly colorless and transparent cleavage piece from a large crystal.

Nathrop, Colorado.—Wine yellow crystals in rhyolite, described by Cross.§ The habit is similar to fig. 4, page 493 of the sixth edition of Dana's Mineralogy, or fig. 54, page 123 of Hintze's Mineralogy.

Utah.—Perfectly colorless transparent crystals from the rhyolite of the Thomas Range, forty miles north of Sevier Lake. The crystals were selected from a suite of specimens in the Brush collection, and have been described by A. N. Alling.‖

San Luis Potosi, Mexico.—Colorless, transparent crystals like those described by Bücking¶ and similar to the ones from Nathrop.

Zacatecas, Mexico.—Colorless crystals similar to the preceding. The material was generously supplied to us by Prof. A. J. Moses, from the mineralogical collection of the Columbia School of Mines, New York.

Schneckenstein, Saxony.—Wine yellow crystals, selected from a suite of specimens in the Brush collection.

Adun-Chalon, Siberia.—The specimen corresponded to the description given by Kokscharow.** A colorless and transparent crystal in the Brush collection was used for the analysis.

* A full description of this method is in preparation and will appear in a later publication.

† Trans. Am. Phil. Soc., Oct., 1885, p. 43.

‡ This Journal, III, xxix, p. 378, 1885.

§ This Journal, III, xxxi, p. 432, 1886.

‖ This Journal, III, xxxiii, p. 146, 1887.

¶ Zeitschr. Kryst., xii, p. 424, 1886

** Materialien zur Min. Russlands, II, p. 232.

Tenagari, Mino, Japan.—The material was taken from a colorless, transparent crystal, in habit like those from Adun-Chalon.

Minas Geraes, Brazil.—Transparent, yellow crystals selected from a suite of specimens in the Brush collection.

We take pleasure in expressing to Mr. Geo. L. English of New York our thanks for generously supplying us with the specimens from Nathrop, San Luis Potosi and Japan.

The following complete analyses have been made:

Utah.

	I.	II.	Average.		Ratio.		Theory for $(AlF)_2SiO_4$
SiO_2	31·93	----	31·93		·532	0·98	32·61
Al_2O_3	56·26	----	56·26		·551	1·015	55·44
F	20·33	20·41	20·37	1·072	1·093	2·02	20·65
H_2O	·19	-- -	·19÷9=	·021			----
			108·75				108·70
O. equivalent to F.			8·58				8·70
			100·17				100·00

Nathrop, Colorado.

			Ratio.	
SiO_2	32·23		·537	0·99
Al_2O_3	56·01		·550	1·01
F	20·42	1·075	1·107	2·03
H_2O	·29÷9 =	·032		
	108·95			
O. equivalent to F.	8·60			
	100·35			

Japan.

	I.	II.	Average.		Ratio.	
SiO_2	32·28		32·28		·538	·98
Al_2O_3	56·61		56·61		·555	1·02
F	19·41	19·60	19·50	1·027	1·090	2·00
H_2O	·57		·57÷9=	·063		
			108·96			
O. equivalent to F.			8·21			
			100·75			

Schneckenstein, Saxony.

				Ratio.
SiO_2	32·82		·547	1·00
Al_2O_3	55·41		·543	1·00
F	18·50	·974	1·077	1·97
H_2O	·93÷9=	·103		
	107·66			
O. equivalent to F.	7·80			
	99·86			

Stoneham, Maine.

	I.	II.	Average.		Ratio.		Theory for $[Al(FOH)]_2SiO_4$ F : OH = 9 : 1.
SiO_2	32·28	32·40	32·34		·539	0·99	32·68
Al_2O_3	56·33	56·33	56·33		·552	1·01	55·56
F	18·56	18·30	18·43	·970	1·080	1·98	18·63
H_2O	1·04	·93	·98÷9=	·110			·98
			108·08				107·85
O. equivalent to F.			7·76				7·85
			100·32				100·00

Brazil.

			Ratio.		Theory where F : OH = 3 : 1.
Si_2O_2	32·53		·542	1·00	32·79
Al_2O_3	55·67		·546	1·00	55·74
F	15·48	·815	1·087	2·01	15·57
H_2O	2·45÷9=	·272			2·45
	106·13				106·55
O. equivalent to F.	6·52				6·55
	99·61				100·00

From the results of these analyses it is evident that fluorine has been replaced by hydroxyl and the ratios indicate very clearly that $SiO_2 : Al_2O_3 : F+OH = 1 : 1 : 2$ as required by either of the following formulæ $[Al(F.OH)]_2SiO_4$ or $[Al(F.OH)_2]AlSiO_4$. The first two analyses show very little hydroxyl, so that the material may be regarded as practically the pure fluorine compound, $(AlF)_2SiO_4$. In addition to the complete analyses, isolated determinations have been made on material from the other localities mentioned on page 390 and these results will be given beyond in tabular form.

Physical properties and their relations to the chemical composition.—The specific gravities were very carefully determined on a chemical balance, pains being taken to boil the crystals for some time in water to expel any air bubbles. The results vary within the limits 3·574 and 3·533, a difference of only 0·041, and as a rule they decrease as the molecularly lighter hydroxyl replaces fluorine.

Also basal plates were prepared and the divergence of the optical axes 2E measured on a large axial angle apparatus. The values for 2E have been found to vary in topaz from different localities and according to the observations of Des Cloizeaux they extend from 129° 30′ on crystals from Durango, Mexico* to 71° 32′ on those from Mugla, in Natolien, Asia Minor,† both measurements being for red. These variations have generally been supposed to be connected with some change in chemical composition, but a satisfactory explanation has never been given. In the following table the measurements that we have made are arranged according to decreasing values of 2E for yellow, and with these the determinations of the specific gravity, fluorine and water are given :

	2E yellow.	Specific gravity.	Fluorine.	Water.
Zacatecas, Mexico,	126° 28′	3·574	----	·18
Thomas Range, Utah,	125 53	3·565	20·37	0·19
Nathrop, Colorado,	125 51	3·567	20·42	0·29
Pike's Peak, Colorado,	122 42	3·567	----	0·48
Tenagari, Japan,	120 59	3·565	19·50	0·57
Adun Chalon, Siberia,	118 46	3·562	19·24	0·58
San Luis, Mexico,	118 17	3·575	19·53	0·80
Schneckenstein, Saxony,	114 28	3·555	18·50	0·93
Stoneham, Maine,	113 50	3·560	18·56	0·98
Minas Geraes, Brazil,	84 28	3·532	15·48	2·45
" " "	------	3·523	----	2·50

On the last mentioned crystal the value of 2E was not measured owing to the strong optical anomalies which the section presented; it was observed, however, that the angle was small. It is evident from the results given in the table that the value of 2E decreases as the percentage of water increases or as fluorine is replaced by hydroxyl, and this relation is so constant that the percentage of water can be told from the value of 2E. It is evident, therefore, that the topaz from Durango, mentioned by Des Cloizeaux as giving the largest value of 2E = 129° 30′, must be the nearest approach to the fluorine compound, while that from Asia Minor, also cited by him as

* Bull. Soc. Min. de France, ix, p. 135, 1886.
† Nouv. rech., Inst. France, xviii, p. 612.

giving the smallest value of $2E = 71° 32'$, must be the richest in water or hydroxyl and poorest in fluorine of any topaz that has thus far been examined.

The indices of refraction also show a progressive change along with the variations of 2E as may be seen by the following determinations, given for yellow light by different investigators.

	2E.	2V.	α.	β.	γ.
Thomas Range, Utah,*	126° 24′	67° 18′	1·6072	1·6104	1·6176
Nerchinsk, Adunchal Mts.,†	121 55	65 30½	1·61327	1·61597	1·62252
Colorless Crystal, Brazil,‡	120 40	65 14	1·6120	1·6150	1·6224
Schneckenstein, Saxony,†	114 17	62 33	1·61549	1·61809	1·62500
" " §	110 12	60 55	1·6156	1·6180	1·6250
Minas Geraes, Brazil,†	86 21	49 37	1·62936	1·63077	1·63747

As hydroxyl replaces fluorine, therefore, the indices of refraction increase and the strength of the double refraction decreases, as shown by the values $\gamma - \alpha$ in the extremes:

Thomas Range, Utah $\gamma - \alpha = 0{\cdot}0104$
Minas Geraes, Brazil $\gamma - \alpha = 0{\cdot}00811$

The crystallographic axes are also affected by the isomorphous replacement of fluorine by hydroxyl. The variation however is not very great and only exact determinations can be used for showing it. Mr. C. A. Ingersoll has kindly made for us some careful measurements on a crystal from the Thomas Range, Utah, which, next to the topaz from Zacatecas, contains the least water of any examined by us, and upon which the forms *o*, 221 and *f*, 021 were well developed and gave beautiful reflections. Also on one from Brazil upon which very exact measurements could be obtained from the *f*, 021 faces only, the other forms, the striated prism and the pyramid *u*, 111, not being suitable for measurement.

Utah.

	Measured.		Measured.	Calculated.
$f \wedge f$, $021 \wedge 0\bar{2}1 = 87° 19'$*		$o \wedge o$, $221 \wedge \bar{2}21 = 105° 10'$		105° 10′
$o \wedge o$, $221 \wedge 2\bar{2}1 = 49 36$*		$o \wedge o$, $221 \wedge \bar{2}\bar{2}1 = 127 47$		127 51

Brazil.

Measured.

$f \wedge f$, $021 \wedge 0\bar{2}1 = 86° 55\frac{1}{2}'$*

The axial ratios are given in the following table and with them a number of others given by investigators who regard them as very exact.

* Alling. This Journal, III, xxxiii, p. 146, 1887.
† Mülheims. Zeitschr. Kryst., xiv, p. 226, 1888.
‡ Des Cloizeaux. Manuel de Minéralogie, p. 475, 1862.
§ Zimányi. Zeitschr. Kryst., xxii, p. 339, 1893.

	$\breve{a}$	: $\bar{b}$:	$\dot{c}$
Utah, Ingersoll	0·528110	: 1 :	0·477115
Urals, Koksharov*	0·528542	: 1 :	0·476976
Schneckenstein, Laspeyres,†	0·531548	: 1 :	0·475973
Brazil, Ingersoll	·····	: 1 :	0·473862

Optical anomalies.—Of the crystals examined by us the only ones that showed optical anomalies were those from Brazil. A basal section of the crystal that was used for the complete analysis showed an interior rhomb, having the outline of the unit prism, surrounded by four symmetrical trapeziums, and two opposite ∨-shaped segments, with their angles turned toward and touching the acute angles of the inner rhomb. The disposition of the parts was practically like that described by Mallard‡ and Mack.§ The extinction directions of the outer segments corresponded almost exactly to that of the inner rhomb. On another crystal from Brazil, for which only the specific gravity and water determinations are given, the optical anomalies were much more marked, and the extinction in the different segments undulatory, so that the divergence of the optical axes 2E could not be measured. When the sections were examined by transmitted light it was evident that they were not homogeneous, since the well defined outlines between the inner rhomb and outer segments indicated a variation in the refractive indices. The structure indicates very clearly the existence of an inner core or older crystal, surrounded by a later growth of topaz of different composition. This idea agrees with the observations of Des Cloizeaux, who found that the central and outer segments of a zonal crystal gave different values for 2E. Since it has been shown that the physical properties vary with the composition all the changes to which such a compound crystal is subjected must give rise to mechanical strains and cause the disturbance in the optical orientation of the different zones.

Comparison between topaz and herderite.—The changes that have been brought about by the partial substitution of fluorine by hydroxyl have previously been studied by one of us, page 329, and it will be interesting in closing to make a comparison of the results that have been obtained. In herderite we know the pure hydroxyl compound, hydro-herderite $Ca(BeOH)PO_4$ and the hydrofluor-herderite $Ca[Be(OH.F)]PO_4$ with $OH : F = 3 : 2$. With topaz the nearly pure fluorine extreme is known $(AlF)_2SiO_4$ and the hydrofluor topaz from Brazil $[Al(F.OH)]_2SiO_4$, with $F : OH = 3 : 1$.

* Materialien zur Minn. Russ., ii, p. 198, 1854.
† Zeitschr. Kryst., i, p. 351, 1877.
‡ Ann Mines, x, p. 155, 1876.
§ Wied. Ann., xxviii, p. 153, 1886.

In both herderite and topaz an increase in hydroxyl is accompanied by a decrease in specific gravity and an increase in the indices of refraction. In monoclinic herderite the axes of greatest and least elasticities correspond nearly to the crystallographic axes, and overlooking this slight deviation the optical orientation in both minerals is the same, $a = a$, $b = b$ and $c = c$. Since topaz is positive and herderite negative the acute bisectrices are c and a respectively, but the angle of the optical axes measured in each mineral over the axis of least elasticity (that is in herderite over the obtuse bisectrix) is smaller for the hydroxyl than for the fluorine compound. In both minerals the substitution of hydroxyl for fluorine causes a change in the lengths of the crystallographic axes but the changes are not of the same character, since in herderite the a and c axes both increase while with topaz a increases and c decreases.

Laboratory of Mineralogy and Petrography,
Sheffield Scientific School, April, 1894.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On the Effect of absorbed Hydrogen on the Electrical Properties of Palladium.*—In a recent paper by Brucchietti, he gives the results of his investigations upon the effect of the absorption of hydrogen upon the thermo-electric power and the electric resistance of palladium. He finds that this absorption increases the resistance, the increase being proportional to the quantity absorbed; a palladium wire saturated with hydrogen having a resistance 1·55 times as great as before it was charged. When the same wire is repeatedly saturated with hydrogen and discharged, its resistance appears to tend toward a constant value (whether hydrogen is present or not); this value being intermediate between its resistance before being charged and that after being charged for the first time. In his experiments on thermo-electric power, the author used a couple consisting of palladium and nickel and found that the power of this couple increases with the amount of hydrogen which the palladium has absorbed; so that when the metal is saturated, the thermo-electric power is 1·66 times that observed before charging. When a thermo-electric couple was made of charged and uncharged palladium, the current at the cooler junction was found to flow from the charged to the uncharged metal.—*Nature*, xlix, 65, November, 1893. G. F. B.

2. *On the Determination of the Molecular Formulas of Liquids by means of their Molecular Surface Energy.*—The

striking and important analogy between the volume-energy equation of a gas and the surface-energy equation of a liquid has recently been investigated by RAMSAY. The former equation has the well-known form $pv=RT$, in which v is the volume of the gas, p the pressure upon it in atmospheres, T the absolute temperature, and R a constant, which when the unit of volume is the volume in liters occupied by the molecular mass in grams, becomes 0·0819. The equation representing the surface-energy of a liquid is $\gamma s = k(\tau - d)$; in which γ is the surface tension, s the surface, k a constant analogous to R and τ the temperature measured downward from the critical temperature. Since the origin of the line representing the variation of surface energy with temperature is not at the critical temperature but about 6° below it, a constant d is subtracted from τ. By a series of experiments with ethyl oxide, methyl formate, ethyl acetate, benzene, chlorbenzene and carbon tetrachloride, the author has shown that the molecular surface energy of liquids which do not dissociate, varies directly with $(\tau - d)$ within very wide limits of temperature. In comparing different liquids with each other it is necessary to select surfaces on which equal numbers of molecules lie. And since the molecular volume of a liquid is that volume in cubic centimeters which is occupied by the molecular mass taken in grams, it is evident that the cube root of the molecular volume gives the relative number of molecules along a line one centimeter long and that the square of this value represents the relative number of molecules distributed on unit surface; i. e., on one square centimeter. Hence the expression $(Mv)^{\frac{2}{3}}$ may be termed the "molecular surface" of a liquid. This quantity multiplied by γ the surface tension, gives $\gamma(Mv)^{\frac{2}{3}}$, the molecular surface energy; i. e., the energy which must be expended in producing a surface on which a definite number of molecules is distributed, this number being the same for all liquids. Since the rate of change of the surface energy with temperature is a linear function of the temperature, the first differential coefficient dE/dt or $d[\gamma(Mv)^{\frac{2}{3}}]/dt$ has the constant value 2·121.

In connection with EMILY ASTON, Ramsay has now applied these considerations to the determination of the molecular formulas of liquids. From the equation $(\gamma(Mv)^{\frac{2}{3}} - \gamma'(Mv')^{\frac{2}{3}})/(t'-t) = 2.121$ or K, we have $M = K(t'-t)/(\gamma v^{\frac{2}{3}} - \gamma' v'^{\frac{2}{3}})$; from which knowing the molecular surface energy at two or more temperatures, the molecular masses can be calculated. The liquids used were such as promised to show a higher molecular mass than that expressed by their ordinary formulas; such as phenol, bromine, nitric and sulphuric acids and phosphorus. The value γ was obtained from the rise of the liquid in a capillary tube, by the ordinary equation $\gamma = \frac{1}{2}rhg\delta$, in which r is the radius of the tube, h the height of the column, g the gravitation constant and δ the density

of the liquid. For phenol, at 46° to 78°, the value of E the molecular surface energy, was found to be 736·9 and that of K 1·682; whence M=133·5. At 131° to 184°, these values were 490·6, 1·899 and 110·9 respectively; the value of K being less than 2·121 but approaching it as the temperature rises. There is therefore in this case some condensation on liquefaction; or as the authors call it, "association." In the case of bromine the value of M obtained between 10·6° and 46° was 202·77 and between 46° and 78·1°, 184·59. It may be assumed that even in the liquid state, therefore, most of the molecules have the formula Br_2; though there is apparently some association with fall of temperature. Nitric acid gave 105·9 for the value of M between 11·6° and 46·2°, and 117·4 between 46·2° and 78·2°; showing that the liquid acid is a mixture probably of HNO_3 and $H_2N_2O_6$. Sulphuric acid, H_2SO_4 is unstable and dissociates on warming into SO_3 and an acid of the composition $(H_2SO_4)_{12}H_2O$ approximately. This acid gave a mean value for K of 0·209; indicating a molecular mass corresponding to $(H_2SO_4)_{32}$. Phosphorus between 78·3° and 132·1° gave a value of 2·205 for K, corresponding to a molecular mass of 117; or practically P_4. Hence it appears (1) that phenol like the alcohols forms complex molecules in the liquid state, which dissociate as the temperature rises; (2) that bromine also is somewhat associated but on rise of temperature gives simpler groupings of Br_2; (3) that nitric acid consists largely of molecular groups $(HNO_3)_2$; (4) that sulphuric acid is a very complex substance at ordinary temperature its complexity being probably not lower than $(H_2SO_4)_{32}$, a rapid diminution taking place above 132°; and (5) that phosphorus in the liquid state has a molecular mass the same as that of its gas P_4.—*Jour. Chem. Soc.*, lxiii, 1089, Sept. 1893; lxv, 167, March, 1894.

G. F. B.

3. *On the Manufacture of Oxygen from Calcium Plumbate.*—It had been observed by Le Chatelier, on investigating the dissociation of calcium plumbate, that in order to evolve the oxygen by heat alone, it was necessary to raise the temperature about 200° higher than was required by barium peroxide; but that, on the other hand, the oxygen is more rapidly and completely reabsorbed from the air at lower temperatures by the plumbate than by the peroxide. KASSNER has now called attention to the fact that while the oxygen can be obtained from the plumbate by heat alone other methods are more advantageous. He especially recommends the following: Porous calcium plumbate is moistened with steam and subjected to the action of washed furnace gases preferably at a temperature below 100°. The carbon dioxide in these gases is rapidly absorbed, the material then consisting of a mixture of calcium carbonate and lead peroxide. This is transferred to a retort kept constantly at a red heat and in this the oxygen is evolved, the evolution being much helped by the introduction of a current of steam. After the oxygen is evolved, the current of steam is continued, and the temperature

raised; when carbon dioxide is set free and may be collected for use. The calcium plumbate is then regenerated by means of a current of air. Peitz has modified this process by decomposing the plumbate by a current of pure carbon dioxide at a red heat. Kassner claims for his plumbate process as advantages over the Brin barium oxide process 1st, obtaining pure carbon dioxide as a by-product; 2d, the use of low temperatures and consequent saving in fuel and in wear and tear of the retorts.—*Chemische Zeitung*, xvii, 1242; *J. Chem. Soc.*, lxvi, ii, 89, March, 1894.

G. F. B.

4. *On the Base-forming Function of Iodine.*—Thus far iodine has been classed solely as a negative or acid forming element. But V. Meyer and Hartmann have now shown that it is capable of acting to form basic compounds, and so is analogous in this respect to nitrogen. In fact trivalent iodine can form a powerful base resembling ammonia and which forms well defined salts with acids. This base is constituted thus: $I\begin{smallmatrix}H\\H\\OH\end{smallmatrix}$ being in its structure similar to hydroxylamine $N\begin{smallmatrix}H\\H\\OH\end{smallmatrix}$. The new substances prepared by the authors are derivatives of this simple form and have the constitution $I\begin{smallmatrix}C_6H_5\\C_6H_4\\OH\end{smallmatrix}I$ and $I\begin{smallmatrix}C_6H_5\\C_6H_5\\OH\end{smallmatrix}$. Meyer was led to suspect this property of iodine from the fact that the group IO seems to give basic properties to the compounds in which it occurs, iodosobenzoic acid for example $C_6H_4(IO)(COOH)$ being a much weaker acid than iodo-benzoic acid $C_6H_4I(COOH)$. It would appear therefore that H. I: O, though called hypoiodous acid, will when isolated be found to be a base. The first new iodine base was produced from iodosobenzene C_6H_5IO, which itself forms salts with acids. By dissolving this substance in the calculated quantity of strongly cooled concentrated sulphuric acid, the solution becomes brown and contains only the sulphate of the new base. On diluting by adding ice and treating with potassium or sodium chloride, bromide or iodide, the halogen salt of the new base is precipitated; this base resembling closely in this respect the metals silver, lead and thallium. From the precipitated iodide thus obtained the free base is obtained by treatment with moist silver oxide. Its solution reacts strongly alkaline, and on evaporation yields a gummy mass. The empirical formula of the iodide is C_6H_5I; but as it decomposes on dry distillation completely into mono- and di-iodobenzene, its molecular formula must be $C_{12}H_{10}I_2$, and the formula of the base $C_{12}H_9I_2.OH$. The chloride is a white curdy precipitate much resembling silver chloride, but crystallizing from warm acetic acid. The bromide is a pale yellow precipitate, similar to silver bromide, fusing at 167°–8°. The nitrate is precipited by nitric acid from the sulphuric acid solution as a white mass, soluble in hot water.

In a subsequent paper the authors describe the diphenyl derivative of the new base which they call *iodonium hydroxide.* On treating iodosobenzene, which has been exposed in a thin layer to sunlight for a few days or better, has been heated for some hours to 60°, with moist silver oxide, the diphenyl derivative of the new base is produced. It appears that the iodosobenzene C_6H_5IO is oxidized to $C_6H_5IO_2$; and the reaction is $C_6H_5.IO + C_6H_5.IO_2 + Ag\ OH = Ag\ IO_3 + HO.I.(C_6H_5)_2$. If a mixture of these iodized benzenes in proper proportion be mixed with silver oxide and agitated for three hours and then filtered, the clear solution on adding potassium iodide yields over ninety per cent of the theoretical quantity of crystals of diphenyl-iodonium iodide. The salts of the iodonium bases strongly resemble those of silver, lead and thallium. The diphenyl iodide forms large and beautifully grouped acicular crystals fusing at 175°–6° and passing into the polymeric mono-iodo-benzene C_6H_5I. The aqueous solution of the free base is very stable, is strongly alkaline and absorbs carbon dioxide. Sodium sulphide precipitates a yellow and ammonium sulphide an orange sulphide.—*Ber. Berl. Chem. Ges.*, xxvii, 426, 502, Feb. Mch., 1894. G. F. B.

5. *Diminution of the force of gravity with the height, determined by weighing.*—Franz Richarz and Otto Krigar Menzel communicate some preliminary results obtained, from a very complete experimental station established in the fortifications at Spandau. Each of the two pans of a balance were provided with rods 2 meters long; upon these rods other scale pans were hung. A direct determination of the difference of weight in these scale pans was made. Futhermore a mass of lead weighing 100,000 kilograms was placed in the space between the two vertical pans. On the upper pan the force of the earth and the attraction of the lead mass act in the same direction. On the lower pan they act in opposite directions. A complete description is given of the installation of the apparatus in a room of the fortress. Unusual precautions were taken to avoid changes of temperature. Only at short intervals, however, could concordant observations be taken. A discussion of the method of weighing is given. The difference of weight obtained was $g_u - g_0 = 0{\cdot}0_6 6523\ m/\text{sec}^2$ while the calculated value was $g_u - g_0 = 0{\cdot}0_6 697\ m/\text{sec}^2$.

The observed value was thus smaller than the calculated value. The authors are now in a condition to carry the investigation to a successful conclusion.—*Ann. der Physik und Chemie,* pp. 559–583, No. 3, 1894. J. T.

6. *A law of candle flames.*—P. Glan, after a careful examination of the illuminating power of candle flames in comparison with their dimensions concludes that equal portions of the flame of different candles radiate the same amount of light. The value of the lighting power of a cubic centimeter of a candle flame can be expressed in terms of $0{\cdot}7035^{cm}$ flame volume of a *Walratkerze.*—*Ann. der Physik und Chemie,* pp. 564–590, No. 3, 1894. J. T.

7. *A ring magnet for obtaining intense magnetic fields.*—Very little attention has been paid to the better construction of powerful electromagnets for physical experiments. In most physical cabinets will be found the Ruhmkorff magnet which was designed before clear ideas of the magnetic circuit had been obtained. H. DuBois has therefore designed a ring-formed electromagnet by means of which experiments with powerful magnetic fields can be carried out. The entire magnet constructed under his direction weighed between 500 and 600 pounds—between suitable conical pole pieces a field of 40,000 C. G. S. units was obtained, over a space whose diameter varied from three to five millimeters.—*Ann. der Physik und Chemie*, pp. 537–549, No. 3, 1894. J. T.

II. Geology and Mineralogy.

1. *The age of the White Limestones near Warwick, Orange Co., N. Y.*—An examination of the geological structure, and a petrographical study, of the white and blue crystalline limestones and associated granites of the regions about Mounts Adam and Eve have been made by Messrs. J. F. Kemp and Arthur Hollick. This is the northern extension of the belt of limestones described by F. L. Nason in the New Jersey Annual Report for 1890 under the title of "The Post-Archæan age of the white limestones of Sussex Co., N. J." (see this Journal, vol. xlii, p. 70, 1891.) The authors of the present paper are "on the whole forced to the opinion that the white limestone is metamorphosed blue," which in its extension in New Jersey contains Cambrian fossils, and think it most reasonable to attribute the change to the granite intrusions. "The limestones near the contact become charged with silicates, either in bunches and irreglar masses or else in general dissemination. These masses are chiefly brownish-green hornblende of a peculiar tint, dark brown biotite or phlogopite, light green pyroxene, titanite, calcite, pyrite and some scapolite. Chondrodite, at times thickly charges the limestone and with it spinel. The white limestone graduates into blue with transitional graphitic forms, and the remote blue limestone shows no metamorphism, and the same belt in New Jersey contains Cambrian fossils." The facts in the case do not seem, to the writer of this article, to warrant the conclusion that the white limestone is of Cambrian age. The presence of Cambrian fossils in a limestone of the same region but everywhere distinctly different from it in color, texture and contained minerals, leave the presumption that it is distinct in age as it is distinct in lithological character from the blue limestone, so long as there is neither fossil evidence to determine any age, nor continuity in the sedimentation to show stratigraphical sequence. I have examined in Arkansas two examples of unaltered, stratified limestones of different geological age, appearing in the same section, with only slight difference in texture, color or position of bedding, which were classified by careful geologists as one continuous limestone. In one case the fossils on one side

the line of separation were found to be of Ordovician age, those on the other side Upper Silurian. In the other case the fossils from below were Silurian and, with only a slight interval between, the strata above contained Carboniferous fossils. In the light of such facts it would seem more reasonable to regard these white limestones of New York and New Jersey as distinct from the blue limestones of the same regions because of their persistent lithological differences until actual evidence in the shape of fossils proves their geological age. The presumption is in favor of the theory of their different age until they can be shown to be continuous, and in the absence of such evidence it is unprofitable to confuse them. A valuable *List and Bibliography of the minerals occurring in Warwick Township*, by HEINRICH RIES, is appended to the paper.—*Granite at Mounts Adam and Eve, Warwick, Orange Co., N. Y., and its contact phenomena.—Ann. New York Acad. Sci.*, vol. viii, pp. 638–654. H. S. W.

2. *The Cretaceous Flora of Long Island.*—Mr. HOLLICK has increased our knowledge of this flora by descriptions of forty-six species, nine of which are new species, in a paper entitled *Additions to the Paleobotany of the Cretaceous formation on Long Island.* Bull. Torr. Bot. Club, by ARTHUR HOLLICK. Vol. XXI, pp. 47–65 and Plates 174–180, Feb. 1894; and in a second paper: *Some further notes on the Geology of the North Shore of Long Island*, Trans. N. Y. Acad. Sci., xiii, pp. 122–132, 1894, has shown the relations of 50 determined species, 23 species being identified with species of the Dakota group, of western North America, 16 also are identified with the lower Atane flora, and 7 with the Patoot flora of Greenland, and a few with other fossil floras.

3. *A Monograph of the Devonian Fauna of the south of England;* by G. F. WHIDBORNE. Vol. I, pp. 1–344 and Plates I–XXXI; Vol. II (parts i to iii), pp. 1–160, and Plates I–XVII. Paleontographical Society, London, 1889–1893.— Prof. Phillips' "Paleozoic Fossils of Devon and Cornwall," in 1841, defined the stratigraphy and paleontology of the Devonian System of England, and has since that time served as the basis for the identification of the system in other regions. The faunas of the Rhenish Devonian, of the Hartz, of Belgium and of France and Spain, of Russia, and of New York and several other tracts in North America have been exhaustively studied, and described, while this typical fauna of the Devonian has, as a whole, remained with little more elaboration than it had fifty years ago. This monograph of Mr. Whidborne's will therefore be of special importance in determining the precise fauna of the original Devonian limestone. The author has confined his descriptions to the fauna of the limestone of Lummaton, Wolborough, Chircombe Bridge and Chudleigh :—thus restricting the monograph to a single fossil fauna. When this shall have been completed we will have before us a definite standard for comparison and correlation.

In vol. i, a single vertebrate bone fragment, 20 species of Trilobites and 15 other Crustacea, 60 species Cephalopods, 116 Gastropods, are described. The second volume begins with the Lamellibranchs, of which 56 species are described, and the Brachiopods are partly done, 86 species having already been noticed. Davidson, in 1882, in the supplement to the monograph on British Devonian Brachiopoda, gave a list of sixty-two species from Lummaton, based upon the material in Mr. Whidborne's and in Mr. Vicary's collections, and some of the species were then described, but here the species are figured and their relations to other allied forms discussed. The monograph is a valuable contribution to the precise definition of one of the standard faunas of the geological time scale; discussion of the fauna itself is reserved for a future communication. H. S. W.

4. *Topaz from Texas;* by GEORGE F. KUNZ, (communicated).—Five crystals, all more or less rolled, showing that they had been taken from the bed of some stream or brook, were lately sent to Messrs. Tiffany & Company, of New York, on the supposition that they might be diamonds. Four of these proved on examination to be topaz crystals. The largest one, of a faint pale green color, with dull rubbed surfaces, somewhat rolled and fractured, and slightly etched faces, resembled the more highly modified crystals of this species from Alabashka in the Urals, and Colorado. Its size was $17 \times 16 \times 12^{mm}$. The following faces have been identified, and verified by measurements with the hand goniometer:—the base, 0.0.1, domes 0.21, and 0.4.1, pyramids 1.1.1, and .121, and prisms 1.1.0, and 1.2.0.

Two crystals were white, with very little form, save that the strong basal cleavage was very apparent. One of the smaller ones was about 10^{mm} in diameter, very much etched, and resembled the etched wine-colored crystals from Cheyenne Mountain, Colorado. No other information was given about them than that they came from near Palestine, Texas,—evidently from the granite rocks.

This is the first noted occurrence of topaz in Texas; and its presence suggests that it may probably be found in connection with other minerals associated with topaz and peculiar to the Urals, Madagascar, Ceylon, and Oxford County, Maine.

In December, 1893, my attention was called by Prof. William H. Hobbs, Professor of mineralogy and metallurgy in the University of Wisconsin, at Madison, to a diamond that had been found in Oregon township, two and one-half miles southwest of Oregon village in Dane County, Wisconsin. Through his courtesy, the stone was sent to me by the finder, Mr. Charles Devine of the place just named. The diamond was found by him while husking corn in October, 1893, in a rough, stony field which had been under the plough for forty years. The bank of clayey earth in which it was found contained a large number of rounded pebbles of quartz, but no other of the associated minerals of the diamond; and as the entire district consists of glacial drift coming

from the north, a diamond-bed is not likely to exist in the immediate vicinity, but is rather to be looked for in the direction from which the drift came. The diamond is a rhombic dodecahedron, deeply pitted with circular, elongated, reniform markings. In color it is slightly grayish-green. It is one of the kind of diamonds, however, of which the color is likely to be superficial, and it would probably cut into a rounded stone. Its weight is three and three-quarters and one-sixteenth ($3\frac{3}{4}\ \frac{1}{16}$) karats. This is the second authentic occurrence of diamond in Oregon, Wis., the other occurrence being that of three small stones, the largest of which weighed ($\frac{25}{32}$) twenty-five thirty-seconds of a karat. A 16-karat diamond was reported to have been found, also in the glacial drift at Waukesha, Wis., in 1884. Some litigation resulted from its finding, and considerable doubt was expressed at the time as to the genuineness of the discovery.

5. *Les Enclaves des Roches Volcanique;* by A. LACROIX (*Ann. de l'Acad. de Macon.* Tome X, 1893, pp. 710).—Nothing perhaps marks more clearly the great advance that is being made in the science of petrology than the appearance of a handbook like this, devoted to a special phase of the subject. The inclusions occurring in volcanic rocks have been previously studied by Professor Lacroix (Bull. de la Soc. Geol. de France, vol. xviii, p. 845, 1890), but in the present memoir he has greatly extended his own work and adds a resumé of the observations of others. According to his method of classification the inclusions are divided into two classes, those whose origin is known or supposed to be not the same as that of the rock in which they occur, as a fragment of schist in basalt, which are called enallogenetic (énallogene), and those whose origin is inferred to be similar, as sanidinite in phonolites and trachytes. These are called homogenetic. The volcanic rocks, for classificatory purposes, are also divided into two classes, the basaltic ones, those of dark color, basic in composition, and which have been reproduced artificially, and trachytic rocks, chiefly feldspathic, which have not yet been made by artificial processes. It is evident that the study of inclusions of the first class is that of extreme contact metamorphism. Many interesting results and theories are given which it would be impossible to discuss here. The volume is well illustrated by a large number of cuts and beautiful colored plates. It will prove of great service to all working petrographers. L. V. P.

6. *The Laramie and the overlying Livingston Formation in Montana,* by WALTER HARVEY WEED, with *Report on Flora,* by FRANK HALL KNOWLTON, (Bull. U. S. Geol. Survey, No. 106.) pp. 68, 6 pl. 1893.—The authors of these papers have given valuable descriptions of the geology and of some of the fossil plants from the rocks studied in the region along the base of the mountains south of the Yellowstone, near Livingston, Montana. The total section in the vicinity of Livingston and in the canyon of the Yellowstone consists of Algonkian schists at the base; 835 feet Cambrian shale, limestones, with some quartzites at the base;

450 ft. Devonian, limestones and some shales; 1900 ft. Carboniferous, limestone below and quartzites and sandstones above; 460 ft. Jurassic sandstones and limestones; 4700 Cretaceous, made up of Dakota sandstones and conglomerates, 600 ft.; 1600 ft. Colorado, argillaceous limestone and bituminous shales, 1500 ft. Montana, sandy shales and argillaceous shales, 1000 Laramie, coal bearing sandstones and shales, capped by 7000 feet of sandstone grits, conglomerates and clays, mainly debris of lavas and volcanic rocks, which the authors have named the *Livingston formation.*

The change in the lithology—rounded Archæan sand and pebbles of the Laramie being capped by the angular volcanic ejectamenta of the higher beds, together with evidence of at least local unconformity, are the characters chiefly relied on by the authors for calling the Livingston formation post-Laramie.

The plant remains are shown to have some Laramie affinities but represent more strongly the Denver flora. Of the 22 species of the Livingston beds having a distribution outside the area examined, 17 are found, as the authors remark, "either exclusively in the Denver or have their greatest development in this formation"; but we notice, also, that 12 of these same 22 species are also found in the Laramie, and 4 other species, not ranging outside this area, are also found in the underlying Bozeman-Laramie. So far, then, even if the horizon be correlated with the Denver beds, the plants rather confirm Dr. White's interpretation of the Denver formation as being equivalent to upper Laramie and not to post-Laramie. The only reported fossil fauna seems to us to weaken the conclusion of the authors. It comes from a "white calcaerous sandstone interbedded with the characteristic dark colored sandstone grits and shale beds of the Livingston about 500 feet above the base." Mr. Stanton has identified the fossils as undoubted Laramie fossils.

Whatever change, therefore, is represented by the passage from rounded water-worn Laramie sands and pebbles to angular volcanic ejectmenta and local unconformity, the fact that the same fauna appears 500 feet above the break shows conclusively that, biologically measured, the time interval was insignificant, and the change in the flora is more likely to have been the result of the climatal changes incident to the volcanic eruptions than to any considerable evolution of the total land floras of the continent. Although we should interpret the Livingston beds to be upper Laramie according to the evidence adduced, rather than post-Laramie as the authors maintain, this does not detract from the value of this excellent contribution to the geology of an interesting region. H. S. W.

III. Miscellaneous Scientific Intelligence.

1. *Bulletin of the American Museum of Natural History*, Vol. V, contains the following articles of geological interest: Art. 1, *Artionyx, a new genus of Ancylopoda*, by H. F. Osborn and

J. L. WORTMAN, pp. 1–18; Art. IX, *On the divisions of the White River or lower Miocene of Dakota*, by J. L. WORTMAN, pp. 95–106; Art. XI, *Ancestors of the Tapir from the Lower Miocene of Dakota*, by J. L. WORTMAN and CHARLES EARLE, pp. 159–180; Art. XVII, *Fossil Mammals of the upper Cretaceous beds*, by H. F. OSBORN, pp. 311–330; Art XVIII, *Characters of Protoceras (Marsh), the new Artiodactyl from the lower Miocene*, by H. F. OSBORN and J. L. WORTMAN, pp. 351–372.

2. *Biological Lectures delivered at the Marine Biological Laboratory of Wood's Holl*, in the summer session of 1893. 242 pp. Boston, 1894 (Ginn & Co.).—This is a series of lectures by original investigators discussing the live problems in the several fields of their work, designed particularly for special students already acquainted with the principles of biological research.

The subjects discussed are the Mosaic Theory of Development, by E. B. Wilson; The Fertilization of the Ovum, by E. G. Conklin; On some facts and principles of Psychological Morphology, by J. Loeb; Dynamics in Evolution, by J. A. Ryder; On the nature of Cell organization, by S. Watasé; The inadequacy of Cell-theory of Development, by C. O. Whitman; Bdellostoma Dombeyi, Lae., by Howard Ayres; The influence of external conditions on Plant Life, by W. P. Wilson; Irrito-contractility in Plants, by J. Muirhead Macfarlane; The Marine Biological Stations of Europe, by Bashford Dean; and an appendix on the Work and Aims of the Marine Biological Laboratory, by C. O. Whitman, the Director.

3. *Star Catalogue.*—The late Dr. Peters and his assistant, Charles A. Borst, at the Litchfield Observatory were preparing an extensive Star Catalogue. The ownership of the manuscript and of the Catalogue has been the subject of legal contest.

The decision was in favor of Dr. Peters; but the Court of Appeals has recently reversed the decision and ordered a new trial. It is to be hoped that under some agreement of the parties the Catalogue may now be completed by Mr. Borst, and published without further delay. H. A. N.

The Rensselær grit Plateau in New York, by T. NELSON DALE. Extracts from the 13th Ann. Rept. of the Director, U. S. G. S. 1891–2, pp. 291–340, with Plates XCVII–CI.

Washburn Observatory of the University of Wisconsin. Vol. VIII. Meridian circle observations 1887–1892. Part I. Results of meridian circle observations, 1888–1890, by Prof. S. J. BROWN, U. S. N., ALBERT FLINT and H. V. EGBERT. With an introduction by GEORGE C. COMSTOCK, Director. pp. 1–300, 1892. Part II, Meridian circle observations of Mars at the opposition of 1892, prepared for publication by ALBERT S. FLINT, Assistant Astronomer, pp. 301–327, 1893.

Ein geologischer querschnitt durch die Ost-Alpen nebst anhang über die sog. Glarner doppelfalte, by A. Rothpletz.—(E. Schweitzerbart'sche Verlangshandlung, Stuttgart. 1894. pp. 268. 1 long plate and 115 cuts in the text.)

A Treatise on Elementary Hydrostatics, by JOHN GREAVES, 204 pp., Cambridge, 1894. (Macmillam & Co., New York, price $1.00.)

APPENDIX.

ART. XLVII.—*Restoration of Elotherium;* by O. C. MARSH. (With Plate IX.)

THE genus *Elotherium*, established by Pomel in 1847, represents a family of extinct mammals, all of much interest. They were first found in Europe, but now are known in the Miocene of North America, not only on the Atlantic coast, but especially in the Rocky Mountain region, and still further west. This family includes several genera, or subgenera, and quite a number of species, some of which contain individuals of large size, only surpassed in bulk among their contemporaries by members of the *Rhinoceros* family, and of the huge *Brontotheridæ*.

Remains of this group have thus been known for nearly half a century, yet, until recently, comparatively little had been determined with certainty regarding the skeleton, or of the skull except the dentition, although Aymard, Leidy, Kowalevsky, and others, have made interesting contributions to the subject. In a late paper,* the writer gave figures of a finely preserved skull, and also of a fore and hind foot, of one of the largest species, *Elotherium crassum*, Marsh, and in the present article an attempt is made to restore the entire skeleton of this animal, to serve as a typical example of the group.

The restoration, one-twelfth natural size, given on Plate IX, represents a fully adult individual, which, when alive, was more than seven feet in length and about four feet in height. The basis of this restoration is the type specimen of *Elotherium crassum*, which was found by the writer in 1870, in the Miocene beds of northeastern Colorado, and described in 1873.† A number of other specimens since obtained in the same region, and still others from essentially the same horizon in South Dakota, all evidently pertaining to this species, were likewise used in the restoration.

* This Journal, vol. xlvi, p. 408, plate viii, November, 1893.
† *Ibid.*, vol. v, p. 487, June, 1873.

The type specimen, although incomplete, includes portions of the skull, with various vertebræ and bones of the limbs and feet, and these were sufficient to determine the general form and proportions of the animal here restored. The additional specimens used are mostly in good preservation, and some of them are almost as perfect as in life. Hence, the skeleton, as represented on Plate IX, is believed to be correct in all its essential features.

Looking at the skeleton, as here shown, it is evident that the most striking features are the large and peculiar skull, and the elongate and slender limbs and feet, characters that do not in themselves suggest the suilline affinities of the animal, which a closer study brings to light. The most notable points in the skull, as here indicated, are the long, pendent process of the malar bone, characteristic of some of the sloths, and the strong projections on the lower jaw. The latter supplement the malar process, but are developed to a greater degree than in any other mammals. Another feature of the skull to which the writer has already called attention is the very small brain-case, which proves that the brain itself was very diminutive. This was also true of the other known species, and was probably the main reason which led to the early extinction of the whole group.

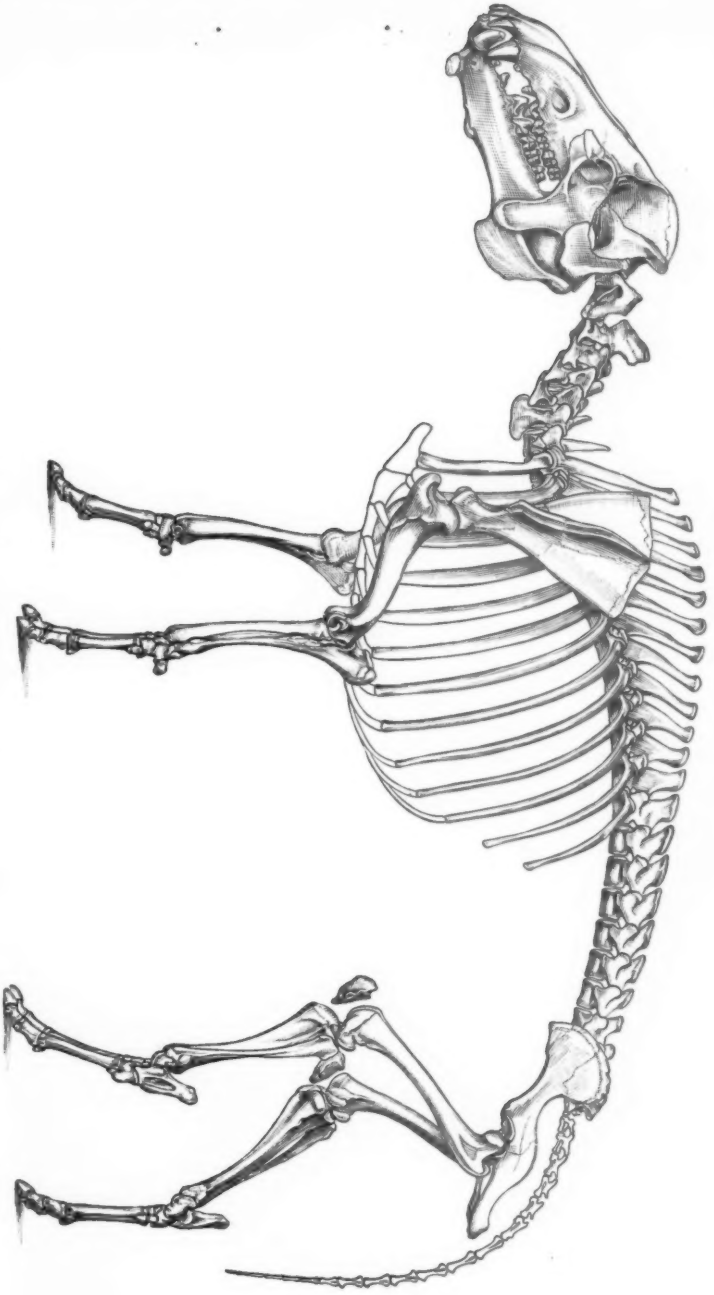
The slender, highly specialized limbs and feet are likewise particularly noticeable in the restoration. They indicate clearly that the animal was capable of considerable speed, and this must have been of great service as a protection from its enemies. It will be seen that in each foot there are only two functional digits, corresponding to the third and fourth in man. The first digit is entirely wanting, and only remnants remain of the second and fifth.

Such reduction was, of course, a gradual process, extending over long geological periods. It indicates clearly a change of environment from the swampy home of the primitive five-toed suilline to the elevated, firm upland of later times, over which the present species and its near allies doubtless roamed. A parallel instance, still more striking, is seen in the gradual change which took place in the equine mammals, as first shown by the writer more than twenty years ago.*

The *Elotheridæ* were evidently true suillines, but formed a collateral branch that became extinct in the Miocene. They doubtless branched off in early Eocene time from the main line, which still survives in the existing swine of the old and new worlds.

Yale University, New Haven, Conn., April 12, 1894.

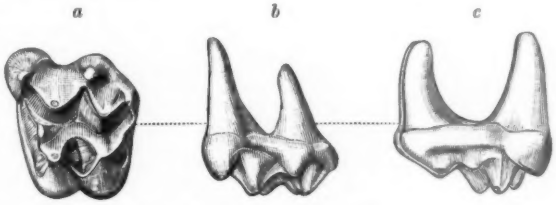
* This Journal, vol. vii, p. 257, March, 1874.



Restoration of ELOTHERIUM CRASSUM, Marsh. One-twelfth natural size.

Art. XLVIII.—*A New Miocene Mammal;* by O. C. Marsh.

Various remains in the Yale Museum seem to indicate a new ungulate mammal, apparently allied to *Hyopotamus*. The specimens, although distinctive, were not found together, and their relation to each other cannot now be determined. A very perfect last upper molar, which may be taken as the type, is shown natural size in the accompanying figures. Its crown is composed of the same main elements as in the corresponding tooth of *Hyopotamus*, but all the five cusps are much less elevated. In addition, the basal ridge of the outer margin is swollen into two high pointed cusps, making seven in all, and this has suggested the generic name.



Upper molar of *Heptacodon curtus*, Marsh. Natural size. *a*, seen from below; *b*, outer view; *c*, front view.

Of the outer cusps, or buttresses, the anterior one is the larger, and is situated well forward and partly outside of the main body of the crown. The antero-median cusp is well developed, triangular in outline, and situated somewhat in advance of the other two anterior cusps, as shown in figure *a*. The two interior cones are connected near their inner margins by a low ridge, and their summits are joined by a high outward-curved ridge, which extends nearly to the centre of the crown. The crown itself is very short, considerably shorter than in the molars of *Hyopotamus*.

The animal thus indicated, which may be called *Heptacodon curtus*, was somewhat larger than a sheep. The known remains are from the upper Miocene of South Dakota.

Yale University Museum, April 14, 1894.

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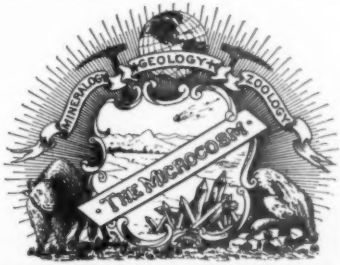

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